Alcohol consumption and cognitive ability in older adults

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Thesis Overview

This thesis explored the relationship between alcohol consumption and cognitive ability in later life. This was achieved by systematically reviewing the literature (Chapter 1), and conducting a longitudinal study using data from the English Longitudinal Study of Ageing (ELSA) (Chapter 2). Both chapters are intended for publication in Ageing and Society and have been written in the style of their publication. The author guidelines for this journal is included in Appendix A.

Improvements in healthcare and technology means people are living longer. It is expected that there will be a 106% increase in the number of people over 85 years living in England by 2040 (Office of National Statistics, 2016). As people age, there is a gradual decline in some cognitive functions, and research has explored the sociodemographic and health factors associated with this decline, such as education, health, and socioeconomic status (Deary et al., 2009). Lifestyle behaviours, such as alcohol consumption, may influence an individual's cognitive decline trajectory, and understanding more about the behaviours associated with maintaining cognitive ability can create opportunities for health promotion and intervention (Plassman et al., 2010). Reduced cognitive ability in old age is one of the most feared aspects of growing old, and is associated with increased risk of mortality, disability, and an overall inferior quality of life (Hedden & Gabrieli, 2004).

Excessive alcohol consumption carries similar risks, and heavy drinkers (consuming >14 units per week) have a reduced life expectancy, and are at greater risk of injury, disability, and cognitive impairment (Wood et al., 2018). Alcohol consumption has been steadily increasing in the general population in recent years, with particularly high rates observed in older adults (Ardnt et al., 2011). Alcohol has a proportionately greater physiological and

cognitive effect on older people, compared to younger adults (Menninger, 2002). Chronic, excessive alcohol use is linked to significant cognitive impairment, and older people may be at a greater risk of this due to the cognitive decline they are experiencing as part of the normal ageing process (Alcohol Concern, 2010; Monds, 2017).

To further explore this topic, Chapter 1 systematically reviews the published literature examining the relationship between alcohol consumption and cognition in older people (65 years+). Studies that assessed the domains of cognition associated with cognitive decline in old age – memory, executive function, processing speed, and reasoning – were included, and the details of the studies were extracted and analysed. The results of the analysis of the review are discussed, and suggestions are made regarding the potential direction of future research in this area.

Following this, Chapter 2 describes a longitudinal study using ELSA data to further explore the association between alcohol consumption and cognition in old age. ELSA is a representative cohort study, collecting data every two years from a cohort of people aged 50 years+, living in England. The present study uses three waves of ELSA data, spanning eight years. The cognitive domains of memory, verbal fluency, and processing speed, and alcohol consumption were used to examine the change in these cognitive functions as people aged and how alcohol influenced this. By focusing on specific domains of cognition related to age-related decline, I aim to produce research that will lead to a deeper understanding of the impact of alcohol consumption on cognition in old age.

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Alcohol consumption and cognition in old age: A systematic review

Abstract

Acute consumption of alcohol has adverse effects on cognitive processing, and increasing age is associated with a gradual cognitive decline. However, there are conflicting reports about the long-term effects of alcohol consumption and cognitive ability in later life. While some studies describe alcohol consumption as beneficial, this runs contrary to findings from alcoholism research, in which chronic, heavy alcohol consumption is associated with severe cognitive deficits. However, many studies reporting a positive association rely on dementia screening tools to assess cognition in healthy older adults. To explore this topic further, a systematic review was conducted to examine the association between alcohol consumption and performance in domains of cognition in old age. Search terms relating to alcohol, cognition, and the older adult population (≥65 years) were used to search CINAHL Plus, PsychInfo, PubMed, and Web of Science databases. Articles were screened using the pre-defined inclusion/exclusion criteria, as registered on PROSPERO. Relevant data from the included studies was extracted, synthesised into summary tables, and analysed. From 2744 studies identified in the database searches, 20 studies were included in data analysis. Overall findings suggested that frequent/ light to moderate alcohol consumption was associated with better performance in all domains, although significant differences between non-drinkers and drinkers/drinker groups were not found in all studies. Results were limited by the underrepresentation of heavier alcohol consumption, across studies. These findings suggest there is evidence of a positive association between frequent/low to moderate levels of alcohol consumption and cognitive performance. However, the ability to consume alcohol in old age may be an indicator of overall better physical health, or greater social engagement. Further research is required to understand the potential adverse effects of heavy alcohol use in the older

population, as this was poorly represented in the included studies. Recommendations for future research include targeted recruitment of older heavy alcohol drinkers, and greater assessment of the sociodemographic and health factors associated with cognition and alcohol use in older age.

Keywords: alcohol, drinking, cognition, cognitive decline, older adults, later life; systematic review

PROSPERO registration: CRD42018084246

Introduction

Alcohol consumption is increasing, and older adults are consuming more alcohol than ever before (Drink Wise, Age Well, 2016). Mixed messages from research and the media are presented about the health consequences of drinking alcohol, with some suggesting alcohol improves cardiovascular and cognitive function (Naimi et al., 2005), whereas others claim that as little as one drink per day is linked with increased risk of stroke (Millwood et al., 2019). Alcohol is well-established as having detrimental consequences on cognition with acute use, and chronic long-term alcohol consumption is associated with adverse changes in brain structure and cognition (Stavro, Pelletier and Potvin, 2013; Topiwala et al., 2017). Cognitive decline occurs as a natural part of ageing, and this puts older drinkers at increased risk of reduced cognitive functioning (Monds et al., 2017). Research into positive ageing and maintaining cognitive ability in later life has gained momentum in the past 20 years, coinciding with a growing elderly population. This paper will systematically review the literature to investigate the association of alcohol use and specific domains of cognition in older adults (65 years+).

Lifespan theories of cognition report that cognitive development begins in utero and continues throughout childhood and adolescence, reaching consolidation in the mid-20s (Clark, Thatcher and Tapert, 2008; Park and Reuter-Lorenz, 2009). Soon after, a gradual decline begins, from the mid-30s onwards, with a steeper decline emerging after age 60 (Salthouse, 2009; Scahie, 2004; Hedden and Gabrieli, 2004). This age-related decline is distinct from the cognitive deficits observed in dementia syndromes, in which the brain begins to atrophy, resulting in a specific pattern of cognitive loss (Nedelska et al., 2016; Montagne, Pa and Zlokovic, 2015). For example, in Alzheimer's disease there is evident impairment in episodic memory, whereas frontotemporal dementia is characterised by executive function deficits and disinhibited behaviour (Graff-Radford and Woodruff, 2007). In non-pathological cognitive decline, domains of cognition are differentially affected (Craik and Bialystock, 2006). The crystallised aspects of cognitive performance, such as language comprehension, mathematical ability, and general knowledge, are considered to remain well persevered into later life (Park and Reuter-Lorenz, 2009). Conversely, the fluid cognitive abilities experience a gradual deterioration from mid-life onwards; memory, executive functioning, reasoning, and processing speed (Deary et al., 2009; Hedden and Gabreli, 2004; Park and Reuter-Lornez, 2009). These cognitive domains are of interest in the present review, as they are well established as showing a change with age. Much of the research into the effects of alcohol on cognitive processes has focussed on the 'working-age' adult population (i.e. those aged 18 - 65 years). In this group, increased alcohol consumption has been associated with adverse performance on tasks of memory, executive function and visuospatial reasoning (Loeber et al., 2009; Saults et al., 2007; Sullivan, Rosenbloom and Pfefferbaum, 2000). Changes in cognition are occurring in these domains during ageing, consequently alcohol use may have a detrimental impact on cognition.

The relationship between alcohol and specific domains of cognition is the focus of this review. Previous research exploring the relationship between alcohol, cognition and ageing has suggested a U-shaped relationship, indicating that non-drinkers and heavy alcohol drinkers perform worse on cognitive tasks than moderate drinkers (Marmot et al., 1981). However, older heavy drinkers are underrepresented in research (Ganguli et al., 2005) and they are more likely to have died prior to the onset of old age, due to health problems or risky behaviours associated with drinking alcohol (Dawson, Goldstein and Grant, 2013; Wood et al., 2018). Equally, the non-drinker group in research samples are often comprised of people who have never drank alcohol as well as people who have quit. These groups are reported to have different characteristics (Choi et al., 2018), although in general, people who abstain from alcohol typically report poorer health outcomes which may impact their cognitive performance (Shaper, 2011).

However, it is difficult to directly compare studies as the definition of 'older adult' or 'late life' is not consistent, with some studies categorising participants as young as 40 as 'older adults' (e.g. Woods et al., 2016). In these studies, the samples range from people in middle age who have not experienced the steeper decline that comes from 60 years onwards (Schaie, 2004) to much older participants, and often there is no subcategorisation of age groups within the sample.

Further compounding the issue is the heterogeneous assessment of alcohol use across different studies. Some studies use dichotomous self-report assessment to categorise participants as drinkers or non-drinkers, while others categorise drinker groups based on assessment of current and/or historical drinking (e.g. McDougall, 2006; Monds, 2017; Sabia, 2014, respectively). Research into the trajectory of alcohol consumption throughout life suggests that older adults typically drink less alcohol but do so more often (Holdsworth et al., 2017; Office of National Statistics, 2012). Formal assessment tools of alcohol consumption

such as the Alcohol Use Disorders Identification Test (AUDIT) (Babor, de la Fuenta, Saunders and Grant, 1992), the 'Cut-down, Annoyed, Criticised, Eye-opener' (CAGE) alcohol misuse screening tool (Ewing, 1984), and the Short Michigan Alcoholism Screening Test – Geriatric version (SMAST-G) (Blow et al.,1992) have been validated for use with the older adult population (Caputo et al., 2012). These self-report questionnaires enquire into alcohol consumption with some focussing on concerns regarding drinking habits, such as the CAGE (Ewing, 1984). Equally, many studies design bespoke assessments to measure volume and/or frequency of alcohol consumption, and both formal and bespoke assessments are accepted in this review as reliable and valid methods of assessment (Moore, Swendsen and Depp, 2016; Sorrocco and Ferrel, 2006).

The assessment of cognitive performance may range from detailed neuropsychological batteries to brief questionnaires. Many studies reporting on cognition in older adults used only screening tests to assess cognitive function, e.g. Mini Mental Status Examination (MMSE) (Folstein, Folstein and McHugh, 1974). These screening tests are designed to assess dementia risk in a clinical setting, and include items relating to time orientation and general knowledge. Due to their brevity and reliability, such assessments of cognition are popular in research, particularly in longitudinal cohort studies. However, in samples of cognitively healthy adults these assessments produce ceiling effects and show little variability, thus limiting their use (Bond et al., 2001; Deary et al., 2009). The present review requires that studies have assessed cognition via domain specific assessments, focussing on the cognitive domains affected by age-related cognitive change and alcohol consumption.

Two systematic reviews published over a decade ago explored alcohol consumption and its relationship with cognitive decline and risk of dementia and in older adults (Peters et al., 2008; Anstey, Mack and Cherbuin, 2009). However, both had relatively small number of studies focussed on age-related cognitive decline, compared to dementia. Alcohol consumption

was associated with reduced likelihood of developing Alzheimer's disease, but no significant associations were observed for cognitive decline in either review. While the variability of alcohol assessment was cited as a limitation, the inclusion of studies that relied on dementia screening tools to assess cognition was not. However, the variability of the age, assessment of alcohol use, and cognitive assessment varies widely in studies focussing on the older adult population.

This the first systematic review to explore the domain-specific associations of alcohol consumption on cognitive performance in older people, without age-related disorders such as dementia and Alzheimer's' disease. There are no limits set for publication date, as previous reviews in this area have found small numbers of studies that focussed on cognitive decline. For the purpose of this review, an 'older adult' is someone aged 65 years or older, in line with the age criteria to access Older Adults' NHS services (https://www.england.nhs.uk/ourwork/clinical-policy/older-people/improving-care-for-older-people/) and other systematic reviews investigating elderly health (Marshal, Bauer and Isenring 2014; Peters et al., 2008). The aim of the review was to answer two distinct questions:

i) Is increased alcohol use associated with reduced cognitive performance?

ii) Is the association consistent across all cognitive domains associated with age-related cognitive decline (memory, executive function, processing speed, and reasoning?

Method

Design

The aim of this review was to investigate the domains of cognition associated with non-pathological ageing and alcohol use in older adults (65 yrs+). The PRISMA (Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines for systematic reviews was followed (See Figure 1.) and a prespecified protocol was registered with PROSPERO (CRD42018084246; last edited on 21/03/2019).

Search strategy and study selection criteria

Searches were conducted using the databases Cumulative Index to Nursing and Allied Health Lifetime Plus (CINAHL), PsychInfo, PubMed, and Web of Science on 22nd March 2019. General limits included quantitative studies with human participants, aged 65 years+, and published in English. The search strategy was developed following analysis of published reviews in the respective areas and through scoping searches. For alcohol, search terms were: 'alcohol' or 'ethanol' or 'wine' or 'beer' or 'liquor' or 'spirit' or 'alcoholism' or '(drinking and behaviour)' or '(alcohol and drinking)' or '(alcohol and consumption)' or '(alcohol and use)' or '(heavy and drinking)' or '(alcohol and abuse)'. For cognition the corresponding search terms were 'cognition' or '(cognitive and function)' or '(cognitive and domain)' or '(cognitive and performance)' or '(cognitive and decline)' or '(cognitive and ability)' or '(cognitive and health)' or 'mental ability' or 'memory' or '(executive and function*)' or 'reasoning' or '(processing and speed)'. Search terms describing an older adult population included: 'older adults' or 'geriatric' or 'retired' or 'elderly' or '(65 and years)'. Hand searching was carried out using the reference list of the full texts included in the review, but no additional studies met the criteria.

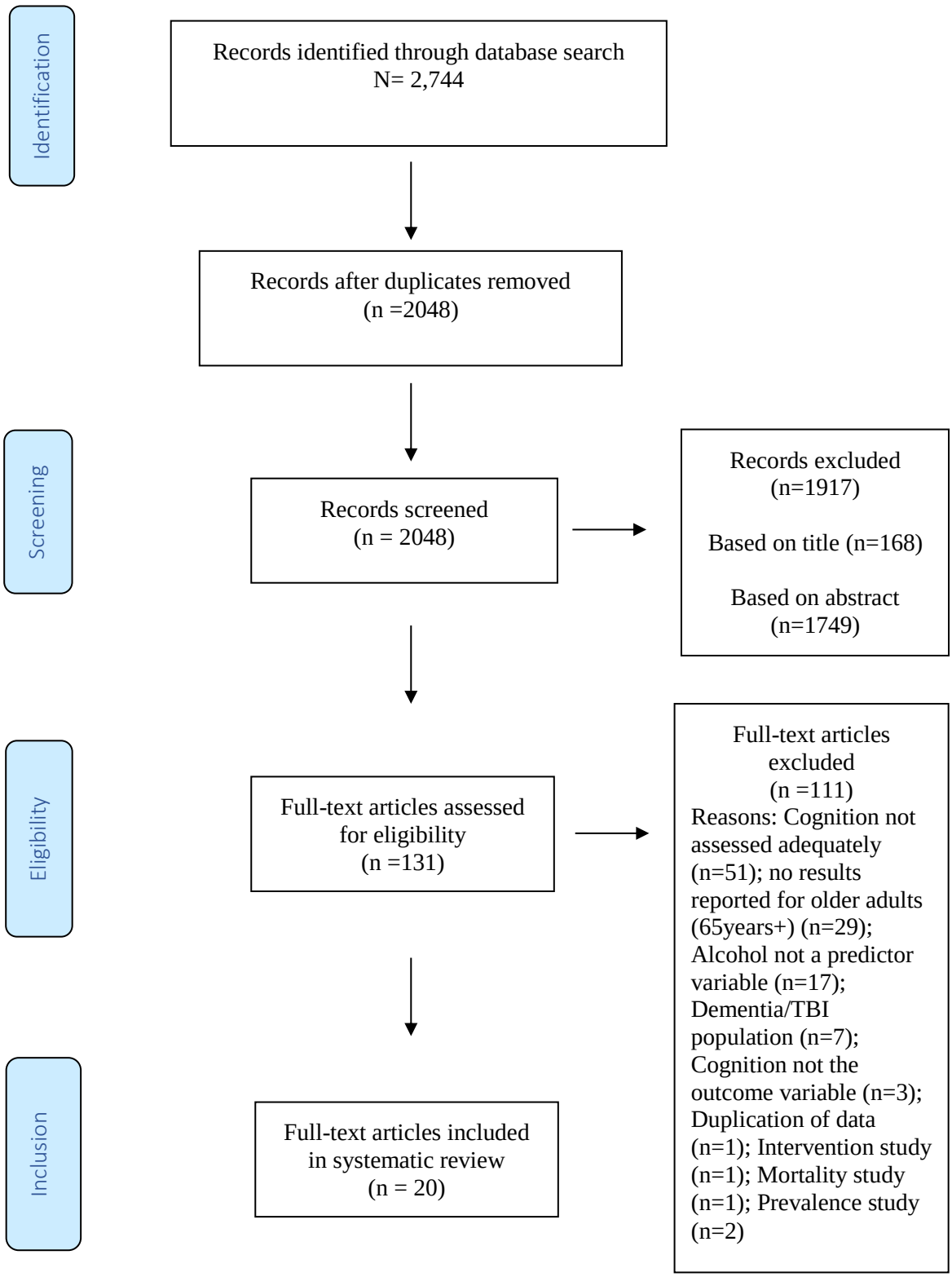

Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

Inclusion criteria

Inclusion criteria for this review required that studies had: i) assessed the frequency and/or volume of alcohol consumption in their assessment of alcohol use, gathered via a standardised measure such or bespoke assessment as part of the study design; ii) assessed domains of cognition related to ageing or alcohol use (memory, executive function, processing speed, and/or reasoning); iii) included a sample or subsample of older adults aged 65 years or older, for which there are reported results.

Exclusion criteria

Studies were excluded from this review if: i) alcohol use was not assessed using frequency or volume of consumption; ii) polysubstance misuse was evident in the sample, as alcohol consumption is the specific area of interest for this review, and other substances may have confounding influences on cognitive performance; iii) cognitive screening tools (MMSE, ACE-III, etc.) were the sole assessment of cognition; iv) criteria for study sample was experience of a specific physical or mental illness or disability in which cognition is well-established to be affected (e.g. traumatic brain injury, encephalitis, delirium, Learning Disability, etc.); v) results were not reported for participants 65 years+; vi) the aim of the study was improving older adults' or alcohol users' cognition (i.e. intervention studies); vii) investigating the risk factors associated with dementia was the focus of the study, as dementia is not of interest in this review; iix) they were case reports, reviews, or letter or opinion articles.

To reduce bias, a second reviewer independently screened a proportion (10%) of the full texts articles and compared these selections with those of the first reviewer. No disputes were raised between reviewers.

Data Extraction

Relevant data was extracted from the final studies that met the criteria. Details of the study characteristics (study design, recruitment, retention/attrition rates, age/sex/size of the sample) are included in Table 1. Details of the of the cognitive and alcohol assessments employed, and associated results of the studies are reported in Table 2.

Quality assessment

Full texts selected for inclusion from the screening process were assessed for risk of bias using the Quantity Assessment Tool for Quantitative Studies (QATQS: National Collaborating Centre for Methods and Tools, 2008; see Appendix B.). The QATQS assesses the quality of studies by evaluating key aspects of the study; selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop-outs, intervention integrity and analyses. Based on the scores for each of these categories, the quality of the study is rated as 'weak', 'moderate', or 'strong'. (See Appendix C. for a breakdown of individual studies scores on QATQS.) QATQS was selected as it is appropriate for observational cross sectional and cohort studies and has been found to have good inter-rater agreement for the final decision to include studies in systematic reviews (Armijo-Olivo et al., 2012).

Results

Screening of articles

A total of 2744 studies were identified from the databases searched, and 696 were identified as duplicates and removed. Of the remaining 2048 studies, 168 were considered to be irrelevant as the title stated the study sample was adolescents/children, non-human or a review. 1880 abstracts were screened and 1749 were excluded based on the inclusion and exclusion criteria

defined by the present review. A large proportion of the studies were excluded as the abstract described samples that were too young (<65 years) or studies relating to cognitive behaviour therapy interventions. The full texts of 131 articles were read and rated against the criteria, and 20 were considered to have met these and included in the final review. The reference lists of these texts were screened, but no additional studies were included.

A large proportion of the studies screened at the full text stage were excluded as the sample was too young (n=29), and age had not been adequately reported in the abstract. Similarly, a detailed description of the assessment of cognition was not always highlighted in the abstract and following further investigation this was found to not have been adequately assessed in number of studies (n=51). Many studies included details of alcohol consumption as part of a larger assessment of health or diet but did not use alcohol as a predictor variable in the analyses, and so the association of alcohol on cognitive performance could not be deduced (n=17). A small proportion of studies were focussed on neuroimaging and neurochemical profiles, rather than cognitive performance, thus cognition was not the outcome variable (n=3); or were related to dementia or traumatic brain injury (n=7); mortality (n=1); or prevalence of cognitive decline (n=2) and were excluded for this reason.

Quality assessment

In assessing the studies' quality, five studies were rated by the reviewer (SG) as 'strong', ten were rated 'moderate' and five were rated as 'weak'. The five studies rated as strong all utilised data from cohort studies, although three were cross-sectional in design. In the assessment of quality, these studies benefited from the large representative samples, detailed account of potential confounders, and robust analyses that non-cohort studies could not always produce. Strong studies were more likely to have appropriately accounted for the potential confounder variables in describing the sample and the analysis. Conversely, weak studies tended to include

few confounder variables, and conduct analyses which could not control for these, which impacted their quality rating (e.g. using t-tests comparing drinker and non-drinker groups (McDougall et al., 2007; Zimmerman et al., 2004). Additionally, attrition/dropout rate was also associated with the weak studies, and the recruitment strategy was often contributed to this. In Beydoun et al. (2014), a large-scale longitudinal study, any participant present for at least two timepoints over a 51-year period was included. Spanning such a broad timeframe may have increased the attrition rate (87.5%), which impacted the study's overall quality rating, as it is unlikely someone who was over 65 in 1958 (the initial wave included in the study) would be participating 51 years later. As regards data collection methods, all the studies included in the review utilised cognitive assessments which had established validity and reliability with the older adult group, which enhanced their quality. In relation to the findings, while one of the strong studies generated no significant findings (Kalapatapu, Ventura and Barnes, 2017), the other four strong studies all reported that light drinking was associated with improved memory and executive function performance (Downer et al., 2015; Hogenkamp et al., 2014; Nurk et al., 2007, Reid et al., 2006). Studies of moderate quality showed a similar pattern. In the weak studies, all reported significant positive associations between alcohol consumption and cognitive performance, although this varied across domains, without a consistent pattern emerging.

Table 1. Characteristics of included studies

First author (year) Country	Study design	Recruitment strategy	Response rate	Attrition rate (if applicable)	Sample size	Age (in years)	Gender split	Quality QATQS
Beydoun (2014) USA	Longitudinal - multiple waves Mean follow-up = 2 years Mean no. of follow-ups= 2	Data from the Baltimore Longitudinal Study of Ageing. Volunteer enrolment to the cohort study via university/online. Sample restricted to participants who had attended two or more consecutive visits between 1958-2009.	-	87.5%	N=338	≥70	43% female	Weak
Bond (2001) USA	Cross sectional	Targeted sampling of older Japanese-Americans to form the baseline of the Kame study. Recruited via letters sent to members of the Japanese American Citizens' League and to persons thought to be of Japanese heritage selected from telephone directory.	65.4%	-	N=1535	Mean = 72 (5.8) Range 65-101	55% female	Moderate
Corley (2011) Scotland	Longitudinal - 2 waves Mean Follow-up (59 years) at age 11yrs and age 70yrs	Targeted sampling of The Scottish Mental Survey (SMS) 1947 to create Lothian Birth Cohort 1936. Participants residing in Edinburgh who completed the SMS at 11yrs were invited by letter for follow-up participation.	36.6%	63.4%	N=992	Mean=69.5 Range 69-71	51.7 % female	Moderate
Downer (2015) USA	Cross sectional	Data from the Framingham Heart Offspring Cohort study (established 1999) which employed targeted sampling to recruit children of participants from the established Framingham Heart Study.	80%	-	N=664	Mean =74.4	55.8% female	Strong
Espeland (2006) USA	Longitudinal - 2 waves Mean follow-up 1.7 years	Targeted sampling from the Women's Health Initiative Memory Study (WHIMS) to create the Women's Health Initiative Study of Cognitive Aging (WHISCA), baseline for this study. Participants were recruited via mailings and at clinic visits.	66%	17.8%	N=2229	Range 65 -80 -65-69 (47.9%) -70-74 (38.2%) -75+ (16.9%%)	100% female	Moderate

First author (year) Country	Study design	Recruitment strategy	Response rate	Attrition rate (if applicable)	Sample size	Age (in years)	Gender split	Quality QATQS
Fischer (2018) Germany	Longitudinal - 8 waves; from 2003 onwards. Mean follow-up= 18 months	Data from the German study on Ageing, Cognition and Dementia in Primary Care patients. Random selection of dementia-free participants from 138 GP clinics in 4 German cities.	50.2%	14.4%	N=2622;	Mean = 81.2 (SD=3.4)	65% female	Moderate
Ganguli (2007) USA	Longitudinal - 3 waves; 1989; 1991; 1994 Mean follow-up=2 years (SD= 2.7)	Data from the Monongahela Valley Independent Elders Survey (MoVIES project). Age-stratified targeted recruitment. Letters of invitation posted to people >65years from the voter registration lists of the Monongahela Valley, Pennsylvania, USA.	54.2%	12.7%	N= 1098	Mean= 74.4 (SD=5.2) Range= 65-97	63.3% female	Weak
Hassing (2018) Sweden	Longitudinal - 5 waves; since 1991 Mean follow-up= 2 years	Data from the Swedish Twin Registry (STR). Targeted sampling of all twins born 1901-1911, potential participants contacted by letter. STR is linked with another Twin study – OCOT Twin Study and cognitive assessment data is taken from OCTO; alcohol assessment is taken from STR.	59.6%	12.2%	N=486	Mean=83 (SD=2.6)	64% female	Moderate
Herbert (1993) USA	Longitudinal- 2 waves; 1982 & 1991 Mean follow-up= 3 years	Targeted age-stratified recruitment at urban community senior centres in East Boston, Massachusetts, USA.	85%	7%	N= 1201	Range=65+	62% female	Moderate

First author (year) Country	Study design	Recruitment strategy	Response rate	Attrition rate (if applicable)	Sample size	Age (in years)	Gender	Quality QATQS
Herring (2018) USA	Longitudinal- 4 waves; 2001; 2002; 2006; 2008 Mean follow-ups= 1.8 years	Targeted age-stratified recruitment from the Health and Retirement Study (HRS) to create the Aging, Demographics and Memory Study (ADAMS).	56.6%	30%	N=856	Mean = 81.5 (SD=7.17)	58.6% female	Moderate
Hogenkamp (2014) Sweden	Longitudinal- 2 waves; 1990; 1997 Mean follow-up= 7 years	Data from the Uppsala Longitudinal Study of Adult Men. Study employed targeted recruitment; in 1970 all men aged 50yrs living in Uppsala County, Sweden, were invited to participate by letter. Followed-up 20 years later and forms the baseline of the study.	82%	26.7%	N=674	Mean =70	100% male	Strong
Kalapatapu (2017) USA	Cross sectional	Data from the Mental Activity and Exercise (MAX) trial. Participants recruited via posters in community centres and flyers posted in the neighbourhoods adjacent to University of California, San Francisco, USA. Planned to follow-up MAX participants and generate a cohort study.	-	-	N=133	Mean= 74.1 (SD=6.4)	53% female	Strong
McDougall (2006) USA	Cross sectional	Opportunistic. Recruited as part of health promotion intervention for older people in which participants are educated about strategies for successful ageing. Recruited via print (posters/flyers), advertisements on local TV media, direct recruitment at city-run senior centres, churches, health fair, festivals in Central Texas, USA.	-	-	N=60	Mean =73.5 (SD=5.6)	100% male	Weak
Moussa (2015) USA	Cross sectional	Opportunistic. Volunteer enrolment via local advertisements (physical flyers and internet) and by word-of-mouth in Wilson-Salem, North Carolina, USA.	-	-	N=41	Mean = 70.6 (SD=3.8) Range 65–80	47% female	Moderate
Ngandu (2007) Finland	Cross sectional	Data from the Cardiovascular Risk Factors Ageing, and Dementia study (CAIDE). Established from the North Karelia (1966) project FINIMONICA (1971) Random sampling via voter registry from areas in Eastern Finland. In 1998, participants of these studies invited to participate CAIDE.	70.5%	-	N=1342	Mean=71.4 (SD=4.0) Range 65-79	62.3% female	Weak

First author (year) Country	Study design	Recruitment strategy	Response rate	Attrition rate (if applicable)	Sample size	Age (in years)	Gender split	Quality QATQS
Nurk (2008) Norway	Longitudinal -2 waves; 1972/1977 (baseline); 1997 - 1999	Data from the Hordaland Homocysteine Health Study (HUSK). Targeted sampling to ensure a young and older adult group sampling from Hordaland, Norway. Participants invited via letter; data accessed from national health services.	77.3%	-	N=2031	Range= 70-74	55% female	Strong
Reid (2006) USA	Cross sectional	Data from a two-year longitudinal study to assess current and lifetime alcohol consumption on cognitive and physical ability of veterans. Targeted recruitment of veterans enrolled in 2 primary care clinics in Connecticut, USA. Participants approached by researchers when attending clinic appointments.	82%	-	N=760	Mean=74 Range 65-89	100% Male	Strong
Wardzala (2018) USA	Cross sectional	Data combined from 2 existing longitudinal studies, both employed voluntary enrolment and report ~1% attrition rates: Oregon Brain Aging study (OBAS) and Intelligent Systems for assessing Aging Changes (ISAAC). Flyers posted in university campus and emails sent to staff and students at Oregon Health & Science University, Oregon, USA	-	~1%	N=486	Mean=81.95 (SD=7.45) Range=70+	69.6% female	Moderate
Zajani et al. (2013) USA	Longitudinal-2 waves; 1998; 2005 Mean follow-up=7 years	Data from the Seattle Longitudinal Study of Ageing (SLS). Participants recruited from Group Health Cooperative a large health maintenance organization in Seattle, randomly selected from the 420,00 members, and invited to participate.	11%	32%	N=489	N =489 Range=65+	56% female	Moderate
Zimmerman (2004) USA	Cross sectional	Opportunistic. Recruited as part of health promotion intervention for older people in which participants are educated about strategies for successful ageing. Recruited via print (posters/flyers), advertisements on local TV media, direct recruitment at city-run senior centres, churches, health fair, festivals in Central Texas, USA.	-	-	N=182	Mean=75	100% female	Weak

Description of selected studies

In this paper 20 studies were systematically reviewed, comprising nine longitudinal studies and 11 cross-sectional studies. Eight of the cross-sectional studies utilised data from cohort studies but focussed on only one data collection point. Over half the studies were from the USA, and the remainder were from European countries.

In longitudinal studies the number of waves of data collection points ranged from one to eight waves, and the length of follow-up ranged from 18 months (Fischer et al., 2018) to 59 years (Corley et al., 2011). A number of cohort studies had specific aims related to the processes coinciding with ageing (e.g. Baltimore Study of Ageing; Mental Activity and Exercise (MAX); Seattle Study of Ageing) with some focussing specifically on the cognitive changes (e.g. German Study on Ageing, Cognition and Dementia; Monongahela Valley Independent Elders Study (MoVIES); Oregon Brain Aging study; Aging Demographics and Memory Study (ADAMS); Women's Health Initiative Study of Cognitive Ageing (WHISCA). Other cohort studies were developed to address health risks of select populations but provided assessment of cognitive function and alcohol consumption as part of data collection (e.g. Cardiovascular Risk Factors Ageing and Dementia Study; Framingham Offspring Cohort Study; Hordaland Homocysteine Health Study; Swedish Twin Registry; Uppsala Longitudinal Study of Adult Men).

The recruitment strategy of cohort studies was often targeted, linked to the studies' grand aims, however some cohort studies (e.g. Seattle Longitudinal Study [established in 1956] and the Baltimore Longitudinal Study of Ageing [established in 1956]), now operate opportunistic recruitment, whereby potential participants apply online. Response rates are included for cohort studies and cross-sectional studies where targeted recruitment was employed. For longitudinal studies, the response rate for the initial cohort studies is reported as well as the attrition rate which ranged from 7.7% to 32.3%.

Table 2. Main findings of included studies

First author (year) Country	*Cognitive domains assessed*	*Cognitive assessments used*	*Assessment of alcohol use* *Categorisation of drinker groups (if applicable)*	*Covariates*	*Analyses*	*Main findings*
Beydoun (2014) USA	Memory Executive function	BVRT (from 1960 onwards); CVLT (from 1993 onwards); WAIS Digits Span Forward and Backward (DS-F, DS-B); Letter & Category Fluency Tests (from 1985 onwards); TMT-A; TMT-B	7-day dietary record. Alcohol assessed in 1961-1965; 1968-1975;1984-1992;1994-2007 Average daily consumption modelled as a continuous variable: Mean=5.8g/day (SD=3.0)	Education; ethnicity; smoking; BMI; age at baseline; year of enrolment	1) Mixed -effects regression models were used to examine associations of baseline alcohol intake with baseline cognitive performance. 2) The relationship of alcohol intake and cognitive change over time and their relationship with cognitive change over time using time interval mixed effects regression models. Time elapsed (y) was measured from age at baseline. Authors Estimated cognitive test scores and plotted their predicted means against time.	1) Cross-sectional analyses: Memory: two tasks DS-F (γ=0.015±0.007, p=0.036) and DS-F (γ= 0.021±0.007, p=0.004) demonstrated significant findings, with greater alcohol consumption associated with better performance. The remaining memory subtasks reported non-significant findings (BVRT γ=0.004 SE=0.017, p=0.814; and CVLT Immediate γ=0.098 SE=0.061, p=0.110; CVLT Delayed γ=0.016 SE=0.019, p=0.410). Executive function tasks failed to report significant findings (Verbal fluency tasks - Letters γ=0.018 SE=0.022, p=0.420; Category γ=0.030 SE=0.016, p=0.59) and on trail making tasks (TMT-A γ= -0.071 SE=0.120, p=0.523; TMT-B γ=-0.344 SE=0.269, p=0.201). 2) Longitudinal analyses: No significant findings were observed in the change over time. Memory: (DS-F γ= -0.000 SE=0.002, p=0.962; DS-B γ=-0.006 SE=0.004, p=0.121; BVRT γ=0.021 SE=0.014, p=0.032 CVLT Immediate γ=0.010 SE=0.017, p=0.53; CVLT Delayed γ=0.000 SE=0.005, p=0.967; BVRT Delayed γ=0.003 SE=0.005, p=0.533).

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Beydoun (2014) USA ***(cont'd)***						Executive function Verbal fluency tasks (Letters γ=0.003 SE=0.004, p=0.348; Category γ=0.002 SE=0.003, p=0.627) and Trails tasks (TMT-A γ =-0.034 SE=0.030, p=0.248; and TMT-B γ= -0.07 SE=0.052 p=0.171).
Bond (2001) USA	Processing speed	3RT test (Teng, 1990)	Monthly consumption Abstainer (73%) Light (<30 drinks/month, 17.7%) Heavy drinker (>30 drinks/month, 8.8%)	Education; income; diabetes; CVD; cerebrovascular disease; smoking; depression	ANOVA examined the association of cognitive performance between the drinker groups.	Reported a significant main effect for drinker group F (2, 729) =3.41, p < .05). with Light drinkers demonstrating greater processing speed than Heavy drinkers or Abstainers.
Corley (2011) Scotland	Memory Processing speed	WMS Logical Memory I Immediate and Delayed Recall, Spatial Span Forwards, and Backwards Verbal Paired Associates Immediate & Delayed Recall WAIS Symbol Search and Digit Symbol; 3 computer-based reaction time assessments	Food Frequency Questionnaire. Non-drinker (no current intake, 13.5%) Low-level (<2 units/day, 50.1%) Moderate (Daily intake of any amount of alcohol, 31.0%) Alcohol modelled as a continuous variable in general linear models.	Education; SES; childhood IQ; smoking; medical history; CVD; stroke; BMI; physical activity	1)ANOVA examined the associations between alcohol intake (units/day) as a continuous variable and cognitive outcome scores for men and women separately. 2) General linear models were used to further examine this association. Effect sizes are reported for this.	1) ANOVAs described the relationships between drinker group and performance on memory and processing speed. Only mean (SD) and p values are reported. Memory: For men, Non-drinkers mean=-0.11(1.00); Low level drinkers mean=-0.12 (0.93); Moderate drinkers 0.24 (0.93), p=0.001). For women (Non-drinkers mean=-0.02(0.94) Low level drinkers mean=0.04(0.98) Moderate mean=0.46(0.88), p<0.001). Processing speed: Men (Non-drinkers mean=-0.02 (0.97); Low level drinkers mean=-0.03 (1.00) Moderate drinkers mean=0.31(0.88), p=0.001) and for women (Non-drinker mean= -0.22 (0.88), Low level drinker mean=0.08(0.88) Moderate mean=0.34(0.92), p=0.002) suggested

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Corley (2011) Scotland ***(cont'd)***						increased alcohol use was associated with better performance. 2) Only p values and effect sizes for the general linear models are reported. Alcohol consumption was significantly associated with memory for women (p=0.043 and men (p=0.30) and medium effect sizes were observed for women (ηp2 =.010) and men (ηp2 =.012). Alcohol had no significant associations with processing speed, and small effect sizes were observed for women (ηp2 =.005) and men (ηp2 =.001).
Downer (2015) USA	Memory Executive function	WMS Word Lists, Digit Span & Stories, Logical Memory Recall, Paired Associates Delayed Recall and Visual Recognition Delayed Recall TMT-A; TMT-B	Average weekly consumption Abstainer (58%) Light 1-6 drinks/week (20%) Moderate 7 14 drinks/week (23%) Heavy 15 - 34 drinks per week (4.6%)	Education; SES; smoking; BMI; blood pressure; chronic health conditions; APOE-4	Multiple linear regression models examined the relationship between late life alcohol consumption and cognitive functioning. Abstainers were the reference group.	Memory: Light drinkers reported significantly better performance than abstainers (β=0.19, SE=0.07 [CI 0.15 - 0.20], p<0.01), but other drinker groups did not (Moderate (β=0.04 SE=0.06, p=0.52; Heavy (β=0.18 SE=0.12, p=0.14. Executive function*: no significant differences between drinker groups and abstainers was found (Light β=0.04 SE=0.08, p=0.59; Moderate β=0.03 SE=0.07, p=0.65; Heavy β=0.23 SE=0.14, p=0.09).
Espeland (2006) USA	Memory	BVRT; CVLT; WAIS Digit Span Test Forwards (DS-F) and Backwards (DS-B)	Food Frequency Questionnaire. Daily volume calculated.	Education, ethnicity, family income, smoking, BMI, years since menopause, hypertension, CVD, diabetes,	General linear models examined the association of baseline alcohol intake on cognitive measures over two waves.	Memory: Non-significant results on all tests, BVRT (Never B=6.98 SE=0.12, p=ns; Light (B=6.76 SE=0.10, p=ns; Moderate drinkers B=6.98 SE=0.18, p=ns) CVLT (Never B=28.02 SE=0.21, p=ns; Light B=28.02 SE=0.16, p=ns; Moderate B=28.11 SE=0.32, p=ns) or Digit Span tasks – DS-F (Never B=7.43 SE=0.07, p=ns; Light B=7.58

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Espeland (2006) USA ***(cont'd)***	Executive function Visuo-spatial ability	PMAV Ekstrom Card Rotations	Alcohol assessed at baseline only. Never-drinkers (32.0%) Light (less than one <1 drink/daily (52.1%) Moderate (>1 drink/daily 14.9%)	hormone therapy; hysterectomy status; treatment assignment		SE=0.06, p=ns; Moderate B=7.61 SE=0.11, p=ns) & DS-B (Never B=6.55, SE=0.07, p=ns; Light B=6.69 SE=0.05, p=ns; Moderate B=6.70 SE=0.10, p=ns. Executive function: – (PMAV) indicating that non-drinkers had the poorest performance (Never-drinkers B=39.79 SE=0.50, p=0.004; Light B=41.46 SE=0.36, p=0.004; Moderate B= 42.05, SE=0 .87, p<0.001). Visuo-spatial ability: Non-significant findings between the drinker groups (Never B=58.51 SE=1.03, Light B=58.31 SE=0.81, Moderate B=56.30 SE=1.55, p=0.46).
Fischer (2018) Germany	Memory	CERAD: Word List immediate, Delayed Recall and Recognition	Frequency of wine consumption. As part of dietary assessment. Never (58%) <once/week (20.5%) Infrequent (7.65%) Frequent (8.85%) Every day (5%)	Education; BMI; smoking; depression; physical activity; APOE-4; cholesterol	Linear mixed effects repeated measures to examine whether the intake of red/white at each wave is associated with memory performance wine over time.	Memory: no significant associations between memory and frequency of red wine (B=-0.04 (CI: -0.11-0.03], p=0.302) or white wine (B=-0.03 [CI: -0.12-0.06], p=0.494) consumption.
Ganguli (2005) USA	Memory	CERAD Word List Learning and Stories, Delayed Recall	Daily/ weekly/ monthly consumption	Education; gender; smoking; depression; volunteering involvement	Trajectory analyses examined the association of alcohol consumption trajectory groups and cognitive	1) Cross sectional analysis: Memory: Minimal drinking was associated with better performance (OR:1.30 [CI= 1.02-1.65], p<0.05), as was Moderate drinking (OR:1.62 [CI=1.13-2.31], p<0.05).

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Ganguli (2005) USA ***(cont'd)***	Executive function Visuo-spatial ability	Initial Letter & Category Fluency; TMT-A; TMT-B Clock Drawing; and CERAD Constructional Praxis	3 homogenous drinker groups defined by trajectory analysis: Non-drinking (40.7%) Minimal drinking (< once a month, 45.7%) Moderate drinking (<once a month, <13.5%).		performance 1) at baseline and 2) average decline in cognition over time. Non-drinkers' trajectory of cognitive decline was the reference.	Executive function: Minimal drinking showed reduced odds of poor performance on TMT composite (OR:1.27 [CI=1.01-1.60], p<0.05) but not fluency task composite (OR:1.17 [CI=0.95-1.44], p=ns). Moderate drinking showed the opposite pattern, with reduced odds of poor performance on fluency composite (OR: 1.37 [CI=1.02-2.40], p<0.05), but not TMT composite (OR:1.30 [CI=0.94-1.82], p=ns). Visuo-spatial ability: Minimal drinkers had reduced odds of poor performance (OR:1.44 [CI=1.12-1.85], p<0.05), as did Moderate drinkers (OR:1.66 [CI=1.15-2.40], p<0.05). 2) For longitudinal analyses, Minimal and Moderate drinking was associated with a significantly reduced likelihood of cognitive decline trajectory on TMT task, and for Minimal drinking also the fluency task. Memory: Minimal drinking (OR:0.38 [CI= 0.10-1.39], p=ns); Moderate drinking (OR:1.06 [CI=0.18-6.33], p=ns). Executive function: Minimal drinking had significant reduced odds of decline on TMT task (OR=0.02 [CI=0.05 - 0.85], p≤0.05) and Fluency task (OR=0.36 [CI=0.15-0.84], p=≤0.05) Moderate drinking was associated with a significantly reduced odds of decline on TMT (OR=0.05 [CI= 0.01 - 0.45], p<0.05),

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Ganguli (2005) USA *(cont'd)*						but not Fluency tasks (OR:0.49 [CI:0.13-1.89], p=ns). Visuo-spatial: Minimal drinking (OR:0.46 CI:0.17-1.24, p=ns); Moderate drinking (OR:0.49 CI:0.13-1.89, p=ns).
Hassing (2018) Sweden	Memory Visuo-spatial reasoning	Prose Recall test; Thurstone Picture Recognition test (TPT) WAIS Block Design	Weekly consumption; assessed at midlife (1967). Non-drinkers (Not in last 12 months, 37.2%) Moderate Drinkers (1-14 units/weekly, 62.8%)	Education; SES; BMI; smoking; depression; stroke; diabetes; hypertension; blood pressure; congestive heart failure; stroke; dementia	In mixed effects growth models analysed the association between alcohol use at baseline (continuous variable) and the rate of cognitive decline across the five waves.	Alcohol consumption was not associated with the rate of decline. Memory: (TPT B=-0.50 SE=0.23, p=0.032; Prose Recall B=0.01 SE=0.07, p=0.879). Visuo-spatial reasoning: No significant association observed on the Block Design task (B=-.0.03 SE= 0.06, p=0.630).
Herbert (1993) USA	Memory	WMS Digit Span and Stories	Weekly consumption Alcohol only assessed at baseline. Non-drinkers (Not in last 12 months, 21%) Very light (less than 15ml/day, 53.4%) Light (15-30ml/day, 11%) Moderate (more than 30ml/day, 14.6%)	Education; income; occupation; smoking; chronic illness	Linear regression analysis was used to examine the effect of baseline alcohol use on follow-up cognitive performance. Non-drinkers as reference group.	Memory: On one subtask, Digit Span, baseline alcohol consumption was significantly associated cognitive performance at follow-up. Very light drinkers performed better than non-drinkers (β= 0.088 [CI= 0.015 - 0.016], p=0.02). No significant associations were found for Light (β= -0.059 [CI= 0.054 - 0.173], p=0.30) or Moderate drinkers (β= 0.068 [CI= -0.042 - 0.179], p=0.20). The other subtask, Stories, no significant associations were observed for Very Light (β= 0.033 [CI= -0.096 - 0.161], p=0.60), Light (β= 0.046 [CI= -0.155 - 0.247], p=0.70), or Moderate drinkers ((β= 0.181 [CI= 0.015 - 0.377], p=0.07).

First author (year) Country	*Cognitive domains assessed*	*Cognitive assessments used*	*Assessment of alcohol use* *Categorisation of drinker groups (if applicable)*	*Covariates*	*Analyses*	*Main findings*
Herring (2018) USA	Memory Executive function Visuospatial reasoning	CERAD Word List Delayed Recall & Recognition; WMS Logistical Memory II Delayed Recall; Fuld Object Memory Evaluation (FOME) CERAD Animal Fluency; COWAT; WAIS Digit Span Test; TMT-B; Symbol Digit Modalities Test (SDMT) BVRT; CERAD Constructional Praxis	Weekly consumption Non- drinkers (no alcohol consumed in last week 83.0%) Moderate drinkers (1-14 drinks/week, 17.0%)	Education; SES; smoking; APOE-4; physical health	Latent growth curve models examined drinkers' performance on cognitive tests at 1) baseline and 2) over time. Non-drinkers were the reference group.	1) In cross-sectional analyses: Moderate drinkers performed better than Abstainers on all tasks except Word List Recognition and TMT-B. Memory: Moderate drinkers performed significantly better on three of four memory subtasks – WMS–R Logical Memory II (β=1.77, $p \leq 0.05$); FOME (β= 2.18, $p \leq 0.01$); and Delayed Word List (β= 0.53, $p \leq 0.05$), but not Word List Recognition (β= 0.20, $p \leq 0.05$). Executive function: Moderate drinkers demonstrated significantly better performance on all tasks (Animal fluency β= 2.13, $p \leq 0.001$); COWAT β=3.60, $p \leq 0.001$); Digit Span (β= 1.30, $p \leq 0.001$); Symbol Digit Modalities (β= 3.24 $p \leq 0.01$)) except TMT-B* (β= -1.19, p=ns). Visuo-spatial ability: Moderate drinkers performed better than Abstainers (BVRT β= 0.37, $p \leq 0.05$), Constructional Praxis β=0.47, $p \leq 0.01$), and Delayed Constructional Praxis β= 0.64, $p \leq 0.05$). 2)In longitudinal analyses, no significant associations were observed between Moderate drinkers and Abstainers on cognitive tests. Memory: WMS–R Logical Memory II β= -0.05, p=ns; FOME β= -0.05, p=ns; Delayed

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Herring (2018) USA *(cont'd)*						Word List β= -0.02, p=ns; Word List Recognition β=-0.02, p=ns. Executive function: Animal Fluency β= -0.02, p=ns; COWAT β= -0.22, p=ns; Digit Span β= -0.09, p=ns; Symbol Digit Modalities β= -0.03, p=ns; TMT-B* β-14.59, p=ns. Visuospatial ability: BVRT β= -0.04, p=ns; Constructional Praxis β= -0.00, p=ns; Delayed Constructional Praxis β= -0.02, p=ns
Hogenkamp (2014) Sweden	Executive function Processing speed	TMT-B TMT-A	Weekly consumption transformed into average volume/day Alcohol assessed at baseline Alcohol as a continuous variable g/day Alcohol categories: drinks per day (no details on the categories) Quintiles based on sample's daily consumption	Education; smoking; physical activity; dietary intake; BMI; diabetes prevalence; cholesterol; hypertension prevalence; blood pressure; APOE-4	Linear mixed models to assess alcohol assessed at age 70 was associated with: 1) cognitive performance at age 70; 2) cognitive performance at age 77. Alcohol was modelled as a continuous variable, categorical and in quintiles.	1) Association of alcohol intake on Executive function: increased alcohol use was associated with faster performance on TMT-B when alcohol was modelled as a continuous variable (g/day; β=-.0869, p<0.001)*, as a categorical variable (drinks/day β= -7.964, p<0.002)* and as quintiles (β= -4.087, p<0.001)*. Processing speed: no significant results were observed on any of the alcohol analytic approaches continuous variable (β= -1.785, p=0.103) categorical (β= -1.785, p=0.103 or quintiles β=-0.119, p=0.852). 2) Alcohol intake at age 70 was not predictive of cognitive performance at age 77, any way that alcohol was modelled: Executive function (continuous [β= -0.325, p=0.471], categorical [β=-3.642, p=0.454], and quintiles [β= -0.743, p=0.736]).

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Hogenkamp (2014) Sweden ***(cont'd)***						Processing speed (continuous [β= -0.020, p=0.878], categorical [β= 0.140, p=0.92] and quintiles [β= -0.119, p=0.852]).
Kalapatapu (2017) USA	Memory Executive function Processing speed Visuo-spatial ability	Rey Auditory Verbal Learning Test (RAVLT) Letter and category test; TMT-B; Eriksen Flanker test; Congruent and incongruent reaction times Digit Symbol Substitution Test Useful field of view (UVOF)	Lifetime Consumption and frequency. Never/minimal drinkers (≤100 drinks in their lifetime, 18.7%) Former (>100 drinks in their lifetime but no alcohol in last 30 days, 17.2%) Current users (>100 drinks in a lifetime and alcohol in the last 30 days 63.1%). Drinking years calculated as age first drink alcohol multiplied by the average no. drinks per week.	Education; ethnicity; occupation; sleep quality; cardiovascular; diabetes; smoking; depression	1)Linear regression examined the association of current alcohol consumption status on cognitive performance. 2) Linear regression examined total number of drinking years for current and former drinkers and cognitive performance	1) No significant results were observed for the three drinker groups on any of the cognitive tasks on any domains. 2) No significant results were observed for drinking years for former and current drinkers on any of the cognitive tasks on any domains.
McDougall (2006) USA	Memory Executive function	Rivermead Behavioural Memory Test (RBMT) (COWAT; TMT-A & TMT-B)	Consumption & frequency. Non-drinkers (42%) Drinkers (58%)	N/A	T-tests to compare drinker groups mean scores on subtasks of memory and executive function.	Only the means for drinker group and significant level of t-test are reported. Only significant result was Drinkers performed better than Non-drinkers on the memory task. Memory: RMBT (Non-drinkers - mean 16.92 (SD=3.64; Drinkers – 19.77 (SD=3.15), p=0.002; pooled effect size d=0.85.

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McDougall (2006) USA ***(cont'd)***						Executive function: COWAT (Non-drinkers mean=39.36 (SD=9.88); Drinkers mean=43.51 (SD=11.83), p=0.157; pooled effect size, d=-0.38); TMT-A (Non-drinkers mean= 46.92 (SD)= 37.83; Drinkers mean=36.74 (SD)=19.38, , p=0.226; pooled effect size d=.36) and TMT-B (Non-drinkers mean=148.76 (SD)=97.52; Drinkers mean=110.94 (SD)=61.09, p=0.095; pooled effect size d=0.48.
Moussa (2015) USA	Working Memory Short term memory Executive function Processing speed	1Back Test; Delayed Match to Sample Test HVLT; Pattern Recognition Test; Spatial Recognition Test; Spatial Span Test Stockings of Cambridge Test; TMT-A & TMT-B; Intra-Extra Dimensional Set Shift Test Reaction Time Test Symbol Digit Modality Test	AUDIT; TFLB Light (<8 drinks/ month and<2 drinks/ week, 45%); Moderate (7–21 drinks/week and <3 drinks/ day; 55%)	BMI; diabetes; blood pressure; depression;	MANCOVA analysis to investigate associations of light and moderate drinkers' performance on cognitive domains.	No difference between Light and Moderate drinkers was observed: Memory: working memory [$F_{(52)} = 1.84$, $p = 0.14$); short- term memory [$F_{(50)} = 1.00$, $p = 0.44$]. Small effect sizes were calculated for all domains working memory (d=0.43), short term memory (d=0.44), Executive function: [$F_{(54)} = 0.93$, $p = 0.40$), with small effect size (d=0.30) observed. Processing speed: [$F_{(54)} = 0.08$, $p = 0.93$], small effect size between groups (d=0.09).
Ngandu (2007) Finland	Memory	WAIS Word List Immediate Recall	Monthly frequency Never (29.5%)	Education; income; living alone; BMI; smoking;	ANCOVA Investigated the relationship between mid-life alcohol	ANCOVA reported significant results for some drinker statuses on domains of memory, executive function and processing speed.

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Ngandu (2007) Finland ***(cont'd)***	Executive function Processing speed	Stroop test (computerised) Purdue Pegboard Test; WAIS Letter Digit Substitution Test	Infrequent (drank <once a month, 41.7%) Frequent (drank >once a month, 28.8%).	depression; stroke; diabetes; cholesterol; blood pressure; cholesterol; APOE-4;	drinking and late life cognition and late life drinking and late life cognition	Memory: Frequent drinkers β= 5.2 SE= 0.1, p=0.02) performed better than Never drinkers β=4.9 SE=0.1, p=0.02.) Executive function*: Infrequent drinkers (β=37.80 SE=1.2, p=0.01) performed better than Never drinkers (β=43.0 SE=1.5, p=0.01). In processing speed, Frequent drinkers (β=0.20 SE=0.0, p=0.01) performed better than Never drinkers (β=-0.02 SE=0.1, p=0.01) No other significant findings were reported between drinker groups on cognitive domains.
Nurk (2008) Norway	Memory Processing speed Visuo-spatial reasoning	Kendrick Object Learning Test (KOLT) TMT-A; WAIS Digit Symbol Test (m-DST) WAIS Block Design	Food Frequency Questionnaire. Frequency and consumption of wine. Alcohol only assessed at midlife 1972 & 1977 Drinkers (43.5%) Non-drinkers (56.5%)	Education; diabetes; CVD; MCI; angina; stroke; hypertension smoking; depression; total energy intake	Linear regression analyses were used to examine associations between cognitive test scores and baseline wine consumption. Risk ratios of poor cognitive performance were reported.	Risk of poor performance on all cognitive domains reduced with habitual intake of wine. Memory: (KOLT, OR:0.51 [CI= 0.36 – 0.72], p<0.001). Processing speed: (TMT-A, OR:0.47 [CI=0.32 – 0.68] p<0.001 and m-DST OR: 0.52 [CI=0.35 – 0.77] p=0.001) Visuo-spatial ability: (OR: 0.059 [CI=0.37 – 0.95] p=0.029).
Reid (USA) 2006	Memory	HVLT	CAGE; TFLB & Lifetime drinking questionnaire; Never (4.08%)	Education, ethnicity, marital status, occupation,	1) Linear regressions for each cognitive subtest used to explore the	1)For levels of consumption, only Light drinkers demonstrated significant associations, all indicating better performance than non-drinkers. Moderate

First author (year) Country	*Cognitive domains assessed*	*Cognitive assessments used*	*Assessment of alcohol use* *Categorisation of drinker groups (if applicable)*	*Covariates*	*Analyses*	*Main findings*
Reid (USA) 2006 ***(cont'd)***	Executive function Processing speed	TMT-B; Letter fluency test (FAS) Symbol Digit Modalities Test (SDMT)	Former (28.94%) Current (66.98%) Light (<7 drinks/week, 81.7%) Moderate (7-14 drinks/week but <14, 10.6%) Heavy (> drinks/ week, 7.7%) Drinking years: based Patterns of alcohol consumption throughout life; calculates the number of drinks per week multiped by the number of years drinking that level.	depression; medical co-morbidity - diabetes, hypertensions, CVD; smoking; emotional support available;	association of light and moderate drinking with cognitive performance. Refence group was non-drinkers. 2)Linear regression to explore the cumulative effect of drinking (measured in drinking years). Analysis restricted to light and heavy drinkers.	and Heavy drinkers had no significant findings on any cognitive tasks. Memory: HVLT (Light β=1.26 SE=0.35, p<0.01; Moderate β=0.59 SE=0.66, p=0.38; Heavy β=0.05 SE=0.75, p=0.95). Small effect size observed (d=.27). Executive function: Trails tasks TMT-B* (Light TMT-B β=-16.27 SE=5.51, p<0.01; Moderate β=-8.40 SE=10.59, p=0.42; Heavy β=-3.29 SE=11.77, p=0.78). Medium effect size observed (d=.68). FAS (Light β=1.61 SE=1.15, p=0.19, Moderate β=0.52 SE=2.19, p=0.81; Heavy β=-1.25 SE=2.46, p=0.61). Small effect size observed (d=.34). Processing speed: SDMT (Light β=3.22 SE=0.64, p<.01; Moderate β=1.63 SE=1.23, p=.19; Heavy β=0.78 SE=1.38, p=0.57). Medium to large effect size observed (d=.78). 2)Years of drinking at light levels was associated with better performance. Years drinking a heavy level (>28 drinks weekly) was associated with poorer performance, but only significant on TMT-B. Memory HVLT (Light β=0.03 SE=0.01, p<0.01; Heavy; β=-0.02 SE=0.02, p=.25). Executive function: TMT-B* (Light β=-0.53 SE=0.18, p<0.01; Heavy β=0.69 SE=0.31, p=0.03) and FAS (Light β=0.02 SE=0.04, p=0.62; Heavy β= -0.04 SE=0.04, p=0.33)

First author (year) Country	*Cognitive domains assessed*	*Cognitive assessments used*	*Assessment of alcohol use* *Categorisation of drinker groups (if applicable)*	*Covariates*	*Analyses*	*Main findings*
Reid (USA) 2006 ***(cont'd)***						Processing speed: (SDMT (Light= β=0.06, SE=0.02, p<0.01; Heavy β=-0.05 SE=0.03 p=.19). No means/SDs were reported in relation to drinking years.
Wardazala (2018) USA	Memory Executive function	CERAD -Word List; Logical Memory Test; Digit Symbol Test Semantic fluency testing; TMT-B	Weekly Consumption Non-drinkers (52.5%) Moderate (<7 drinks/week currently, 30.0%) Heavy (>7 drinks/week, 17.5%)	Education, ethnicity, Cumulative Illness Rating scale, APOE-4, BMI, diabetes, hypertension	Mixed models were used to explore moderate and heavy alcohol consumption on cognitive ability. Rare/never drinkers were the reference group.	Only selected results were reported. Memory: Significant findings observed on one memory task indicating Moderate performed better than Non-drinkers (Logical Memory Delayed Test) (t=2.77, p=0.007). No significant associations for the other memory subtests (Word List or Digit Symbol Test) or relating to other drinker groups were observed in the study, and the results are not reported. Executive function: no significant results were found in the study and the results are not reported.
Zanjani (2013) USA	Memory Processing speed	Thurstone's Primary Mental Ability test (TPMA) - Immediate & Delayed recall and Word Fluency TPMA Identical pictures; Findings A's & Number	Weekly Consumption Abstainer (no alcohol in past week, 42%) Moderate (<7 drinks/ last week, 44%) Heavy/'At-risk' (>7 drinks/ last week, 14%).	Education, gender, income, smoking	Linear models for each cognitive domain modelled by drinking status x time with age (65-74 or 75+) as a categorical variable.	Only selected results are reported in the paper. Memory: In linear models found no significant differences found between drinker groups, details of results not reported. Medium Effect size observed (d=.47) Processing speed: In linear models no significant differences found between drinker

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Zanjani (2013) USA ***(cont'd)***	Verbal Reasoning Visuo-spatial ability	Comparison (Ekstrom et al., 1976); TPMA Letter Series, Word Series & Number series TPMA Space, Object Rotation, Alphanumeric Rotation &Cube Comparison				groups, details of results not reported. Medium to large Effect size (d=.75) Verbal reasoning: In linear models no significant differences found between drinker groups, details of results not reported. Medium Effect size (d=.57) Visuo-spatial ability: In 65-74yrs group across drinking status (Abstainers B=3.4527, SE=0.425, p=0.001; Moderate drinkers B= 1.733, SE=0.663, p=0.001; 'At-risk' drinkers: B=3.4151, SE=1.165, p=0.003), indicating Abstainers showed the greatest decline, followed by 'At risk' drinkers, with Moderate drinkers having the best performance. In 75yrs+ group, significant findings were reported for Abstainers (B=3.492, SE=0.6446, p<0.001) and Moderate drinkers (B=1.5655, SE=0.715, p<0.001) but no significant decline for 'At-risk' drinkers (B=1.6224, SE=1.131, p=0.21), suggesting a greater decline for Abstainers drinkers over 75, compared to Moderate drinkers. Medium effect size (d=.57) observed.
Zimmerman (2004) USA	Memory	Rivermead Behavioural Memory Test (RBMT)	Weekly consumption Drinkers (43%) Non-drinkers (57%)	Education	T-tests and ANCOVA to explore if older women who drink moderate amounts of alcohol differ from non-drinkers in	Memory: No significant associations in ANCOVA analysis, results not reported. Executive function: Drinkers performed better than non-drinkers on two of three subtests TMT-B* (F(2, 181)=7.29, p<0.01) and COWAT (F(2, 181) =9.21, p<0.01),; but

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Zimmerman (2004) USA ***(cont'd)***	Executive function	COWAT TMT-A; TMT-B			cognitive performance.	not TMT-A* F(2,181)=3.76, p=ns). Medium effect sizes for COWAT (d=.58), TMT-A (d=0.55) and TMT-B (d=0.62) were observed.

* Lower score indicated faster/better performance

Cognitive assessments: BVRT= Benton Visual Retention Test; CERAD= Consortium to Establish a Registry for Dementia; COWAT= Controlled Oral Word Association Test; CVRT= HVLT= Hopkins Verbal Learning Test; WAIS=Weschler Adult Intelligence Scale; WMS= Weschler Memory Scale; PMAV= Primary Mental Abilities Vocabulary Test; TMT-A = Trail Making Trials A; TMT-B = Trail Making Trials B; TPMA= Thurstone's Primary Mental Ability test

Alcohol assessments: AUDIT= Alcohol Use Disorder Identification Tool; CAGE = Cut down, Annoyed, Guilty, Eye-opener; TFLB= TimeLine Follow-Back

Covariates: APOE-4= Apolipoprotein E; BMI= Body Mass Index; CVD= Cardiovascular disease; MCI= Myocardial infarction; SES= Socio-economic status

The majority of studies included male and female participants, although two studies had female-only samples (Ngandu et al., 2007; Zimmerman, McDougall and Becker, 2004), and three studies featured only male participants (Hogenkamp et al, 2014; McDougall et al., 2007; Reid et al., 2006). There tended to be a greater percentage of female participants compared to male in the included studies, with only three studies where the opposite was observed (Moussa et al., 2015; Wardazala et al., 2018; Beydoun et al., 2014).

Across the studies, participants ranged in age from 65 to 101 years of age. Despite most studies describing age as a key research focus, there was often limited detail reported about the age of participants in the included studies. In studies where older adults (65yrs+) were a subsample among other age groups, details about this group were not always clear (Beydoun et al., 2014). In other studies, standard deviations for mean age (Downer et al., 2015; Reid et al., 2006) or age ranges (Corley et al., 2011; Fischer et al., 2018; Hassing, 2018; Herring and Paulson, 2018; Wardazala et al., 2018; Zimmerman et al., 2004) were not reported. Other studies reported the descriptive statistics for drinker type or age groups separately and did not report a total mean age for the sample (Espland et al., 2006; Herbert et al., 1993; Zanjani et al., 2013). However, as inclusion criteria for this review was a sample over 65 years of age, failure to report an exact mean age was not reason for exclusion.

Alcohol assessment

Three studies employed specific alcohol use standardised measures in the assessment of alcohol use; AUDIT (Moussa et al., 2015); CAGE (Reid et al., 2006); Lifetime Drinking Questionnaire (Kalapatapu et al., 2017; Reid et al. 2006); and the TimeLine Follow Back (Moussa et al., 2015; Reid et al., 2006). Three studies used the Food Frequency Questionnaire to obtain data relating to alcohol consumption (Corley et al., 2011; Espeland et al., 2006; Nurk et al., 2007). The remainder of the studies used bespoke assessments which enquired about

consumption and/or frequency and calculated a weekly or daily amount of alcohol consumed. Only two studies relied on a frequency-only assessment of alcohol consumption (Fischer et al., 2018; Ngandu et al., 2007). Alcohol data most commonly generated categories relating to drinking behaviour, however three studies used alcohol as a continuous variable in the main analyses (Beydoun et al., 2014; Corley et al., 2011; Hassing, 2018). Two studies used alcohol differently; Hogenkamp et al. (2014) performed three separate linear regression analyses using alcohol as a continuous (g/day), and categorical (drinks/day) variable and lastly as quintiles derived from the alcohol consumption data; Ganguli et al. (2005) employed trajectory analysis to generate drinker groups within the data. In categorising the drinker groups, the approach to this varied between studies. Four studies defined two categories: 'non-drinkers' and 'drinkers' (Herring and Paulson, 2018; McDougall et al., 2007; Nurk et al., 2007; Zimmerman et al., 2004). In more detailed categorisation of drinkers, there were some consistent patterns corresponding to national drinking guidelines and defined as 'light drinkers' (<7 drinks/week); 'moderate drinkers' (7-14 drinks/week), and a 'heavy drinker' (>14 units per week) (Downer et al., 2015; Reid et al., 2006). Some differences were observed across studies however, a 'very light drinker' (<0.5 fl oz /day; average glass of wine is 5fl oz) category was included in one study (Herbert et al., 1993), and 'moderate drinker' spanned 1-14 drinks/week in another (Herring and Paulson, 2018). Similarly, two studies defined 'heavy/at risk drinker' as consuming >7 drinks/weekly, which other studies would have categorised as 'moderate' (Wardazala et al., 2018; Zanjani et al., 2013).

Only five of the 20 studies included a heavier alcohol consumption group, and the proportion of the sample was typically low, ranging from 4.6% (Downer et al., 2015) to 8.8% (Bond et al., 2001). Importantly, 'non-drinkers' across the studies were not exclusively participants who abstained from alcohol but were participants who had not drank alcohol in the designated time frame of a study's assessment, e.g. no alcohol in in the last week (Zanjani

et al., 2013; Wardazala et al., 2018; Zimmerman et al., 2004) or 12 months (Herbert et al., 1993).

Cognitive domains assessed

Cognitive domains of memory, executive function, processing speed, and verbal and visual reasoning were assessed in studies included in this review. Studies varied in the number of cognitive domains they assessed, and in the selected cognitive assessment used. Seven studies utilised more than one cognitive assessment to assess a single domain, whereas the remaining 13 studies used one selected subtask to represent one domain. Memory was assessed in 19 studies, with two studies assessing no other cognitive domain (Fischer et al., 2018; Herbert et al., 1993). Many of the measures used to assess memory were subtasks from neuropsychological test batteries, relating to word or number list recall, most commonly taken from the Consortium to Establish a Registry for Alzheimer's Disease neuropsychological assessment battery ([CERAD], Heyman, Fillenbaum and Nash, 1997) and various editions of the Weschler Adult Intelligence Scale (Weschler, 1944). Executive function was included in 13 studies, with Trail Making Tests (Reitan, 1971) and verbal fluency most commonly used to assess this. Formal assessment of verbal fluency included Controlled Word Association Test (COWAT) from the Multilingual Aphasia Examination (Benton, Hamsher, and Sivan, 1983), the F-A-S test (Benton, 1967); and the Primary Mental Abilities Vocabulary Test ([PMAV] Thurstone and Thurstone, 1963). Processing speed was assessed by nine studies with great variation in the measures used, as no two studies used the same assessment. All tests were based on participants accurately completing tasks as quickly as possible. Reasoning, the ability to solve verbal or visuo-spatial puzzles was assessed by seven studies in this review, also with considerable variation in the cognitive assessments used.

Alcohol consumption and cognitive domains

The second aim of this review was to examine the association of alcohol consumption with performance on cognitive domains in older adults. The general findings indicate that light to moderate alcohol consumption was associated with better performance on all of the domains assessed, although this was not a consistent finding. Two cross-sectional studies (Kalapatapu et al., 2017; Moussa et al., 2015), and one longitudinal study (Fischer et al., 2018) reported no significant association of alcohol consumption on any of the cognitive domains. Moussa et al. (2015) compared light (<7 drinks/week) and moderate drinkers (7-14 drinks/week) and had no non-drinker group. There may not have been enough difference between these two drinking levels to generate a significant difference, and small effect sizes were observed in the study. Kalapatapu et al. (2017), a strong study, categorised drinkers as never, former and current, and reported that further stratification of these groups may have resulted in different findings. In the longitudinal study, Fischer et al. (2018), wine consumption was the only alcohol of interest, and a large proportion of the sample (58%) never drank wine. In the other studies, all domains demonstrated an association with alcohol consumption, although this appeared to be positive, contrary to our hypothesis. There was variation between the studies' findings in relation to cognitive domains, which are discussed below.

Memory and alcohol consumption

Nine studies reported improved performance for alcohol drinkers on memory tasks (Beydoun et al., 2014; Downer et al., 2015; Ganguli et al., 2005; McDougall et al., 2007; Reid et al., 2006; Ngandu et al., 2007; Nurk et al., 2008; Herring and Paulson, 2018; Wardazala et al., 2018), while two reported no significant difference between alcohol consumption/drinker groups and non-drinkers (Hassing, 2018; Zimmerman et al., 2004). However, there was some variation in the findings within studies when memory was assessed using two subtasks or more,

there was often inconsistent findings between the memory scores in the studies (Beydoun et al., 2014; Herbert et al., 1993, Wardazala et al., 2018). The subtasks correspond to subdomains of memory such as immediate/delayed memory or recognition, but further comparison cannot be made as too few studies used the same subtasks. Beydoun et al. (2014) in their cross-sectional regression analyses found that increased alcohol consumption was associated with improved memory on digit span tasks, but not CVLT tasks. Additionally, the association on digit span did not continue to longitudinal analyses. Two more studies, using only longitudinal data, reported no significant findings relating to memory observed no significant findings for memory (Espeland et al., 2006; Zanjani et al., 2013). Conversely, four other longitudinal studies reported light/moderate alcohol use was associated with better memory (Corley et al., 2011; Ganguli et al., 2005; Herring and Paulson, 2018; Herbert et al., 1993). Minimal and moderate drinking trajectories were associated with reduced likelihood of memory decline in trajectory analyses comparing drinkers' cognitive performance at three timepoints (Ganguli et al., 2005). Importantly, one longitudinal study which reported a small effect size in the positive association of alcohol consumption and memory, explained this apparent improvement for drinkers by the confounding effect of higher prior cognitive ability (IQ at age 11) on later life cognitive ability (Corley et al., 2011).

Executive function and alcohol consumption

Four cross-sectional studies demonstrated a positive association of light alcohol consumption on executive function tasks (Downer et al., 2015; Ngandu et al., 2007; Reid et al., 2006; Zimmerman et al., 2004). However, two studies, one reporting only the means (McDougall et al. 2007) found non-significant results for alcohol use and executive function tasks in cross sectional studies. Wardazala et al. (2018) used mixed models in the analysis of moderate and heavy drinkers and found no significant associations for fluency or trail-making tasks. Of the

six studies using longitudinal data, two reported no significant associations (Hogenkamp et al., 2014; Beydoun et al., 2014). While alcohol consumption at baseline was positively associated with executive function in elderly men, the association was not significant at follow-up seven years later (Hogenkamp et al., 2014). Similarly, alcohol as a continuous variable had no significant associations with executive function tasks in cross-sectional or longitudinal analyses (Beydoun et al., 2014). Three longitudinal studies reported significant findings, although there was some difference in the subtasks. Herring and Paulson (2018), using growth curve modelling, reported moderate drinkers performed better than non-drinkers on fluency tasks but not the trail making task. Espeland et al. (2006) also reported a positive association of alcohol consumption with the fluency task, with light and moderate drinkers outperforming non-drinkers. Likewise, in trajectory analyses of cognitive decline, minimal and moderate drinking was associated with reduced risk of decline in performance on the executive function domain compared to non-drinkers (Ganguli et al., 2005).

Processing speed and alcohol consumption

In cross-sectional studies assessing processing speed, light/frequent drinkers performed better than non-drinkers on three occasions (Bond et al., 2001; Reid et al., 2006, Nurk et al., 2008; Ngandu et al., 2007). ANOVA analysis found that light drinkers, compared to moderate or heavy, were the fastest at a computerised reaction time task, but there was no significant difference between the moderate and heavy groups (Bond et al., 2001). Frequent drinkers (>once a month) were also found to have faster performance than participants who never drank (Ngandu et al., 2007). Nurk et al. (2008) reported a reduced risk of slow processing speed in old age was associated with drinking alcohol in middle age. Three further longitudinal studies assessed processing speed (Corley et al., 2011; Hogenkamp et al., 2014; Zanjani et al., 2013),

and while none reported significant findings, one study reported a medium-to-large effect size in favour of moderate drinkers' processing speed ability (d=0.75; Zanjani et al., 2013).

Reasoning and alcohol consumption

In cross-sectional analysis, the odds of poor performance in reasoning tasks reduced with regular alcohol consumption (Nurk et al., 2007). Growth curve modelling found that moderate drinkers performed significantly better than non-drinkers, and trajectory analysis showed minimal drinking was associated with reduced odds of poor reasoning ability, however these findings were not duplicated in longitudinal analyses of the same data (Herring and Paulson, 2018; Ganguli et al., 2005). Three more longitudinal studies assessed reasoning. Zanjani et al. (2013), found that abstainers showed the greatest decline in visuo-spatial reasoning with time, compared to drinkers in linear regression analysis. In the same study, no significant findings were reported for verbal reasoning, although a medium effect size was noted (d=.57). The two other longitudinal studies reported no significant change associated with alcohol consumption and time, and effect sizes for these studies were not available (Espland et al., 2006; Hassing, 2018).

Increased alcohol use and cognitive ability

The second aim of the review was to explore if an increase in alcohol consumption was associated with poorer cognitive performance in old age. As discussed above, light drinking in contrast to abstaining from alcohol consumption was positively associated with cognitive performance. In studies that used alcohol as a continuous variable, the same trend was reported, although these studies did discuss the relatively low alcohol consumption in their samples (Beydoun et al., 2014; Corley et al., 2011; Hogenkamp et al., 2014). 'Heavy drinkers' as categorised by the studies failed to have any significant associations, in any of the studies'

analyses. For studies that described heavy drinkers as those consuming more than the weekly recommended guidelines, (i.e. more than 14 drinks/weekly) despite a lack of significant findings in regression analyses, the coefficients indicated heavier drinkers demonstrated poorer performance on memory, executive function, and processing speed tasks (Downer et al., 2015; Reid et al., 2006). One study using the number of years drinking at a heavy level (>28 drinks/weekly), reported consistent poorer performance of this group on memory, executive function, and processing speed tasks, although only executive function achieved the significance level ($p<0.05$; Reid et al., 2006). However, another study, also using drinking years as a method of assessment did not find the same pattern and observed small and variable differences between drinkers (Kalapatapu et al., 2017).

Discussion

The aim of this review was to explore the relationship between alcohol consumption and cognitive ability in old age. Specifically, the review examined whether increased alcohol use was associated with reduced cognitive performance and whether this association is consistent across cognitive domains. Overall, the findings from both cross-sectional and longitudinal studies ranging in quality, suggest that light to moderate levels of alcohol consumption are associated with better performance in the cognitive domains of interest: memory, executive function, processing speed and reasoning. However, this was not consistently reported across the studies and these findings should be interpreted with caution; a causative link between increased alcohol use and improved cognition is not advocated. The under-representation of heavy alcohol drinkers and 'survivor effects' of generally healthier people into old age may have contributed to the present findings.

In line with previous studies describing the U-shaped relationship between alcohol consumption and cognition, the findings of this review described non-drinkers as the poorest

performing group, with light to moderate drinkers as the best, although no significant findings were reported for heavy drinkers. The included studies varied in terms of quality, but both cross-sectional and longitudinal studies reported similar patterns, although fewer longitudinal studies had significant findings. An additional aim of this review was to explore the association of alcohol consumption with performance on specific cognitive domains to ascertain if they are differentially associated in old age. All of the domains assessed: memory, executive function, processing speed, and reasoning, demonstrated a positive association with light to moderate alcohol consumption in multiple studies. These findings were reported by both cross-sectional and longitudinal studies, and in weak, moderate and strong studies, indicating alcohol consumption was associated with better cognitive performance, and that this persisted as people aged. However, there are challenges in directly comparing the cognitive domains between studies. There was variation in the cognitive assessments used, and to which cognitive domain they corresponded. For example, the Trail Making Trial A (TMT-A; Reitan, 1971) was used to assess processing speed in one study (Hogenkamp et al., 2014), and in others the scores from TMT-A and Trail Making Trial B (TMT-B) were combined to create a composite executive function score (Beydoun et al., 2014; McDougall et al., 2006; Moussa et al., 2015; Ganguli et al., 2005). However, this overlap in assessing different aspects of cognition is reflective of the natural overlap that exists between cognitive domains. Cognitive processes are highly complex and while theoretically domains of cognition may appear distinct, in reality it is difficult to assess these processes in isolation (Moreira et al., 2016). Executive function is a case in point, while classified as a single domain in this review and the included studies, it is a multifaceted cognitive process incorporating attention, working memory, inhibition, planning, reasoning, and processing speed (Baddeley, 1998). The studies included here assessed aspects of this, but they may not reflect the complexity of this cognitive ability. However, even in direct comparison of individual assessments, there was variability in the results. Returning to

the Trail Making Trials (TMT-A, TMT-B) (Reitan, 1971), the findings were not consistent; there was positive associations for light and moderate drinking (Ganguli et al., 2005; Hogenkamp et al., 2014; Reid et al., 2006) as well as non-significant findings reported for this group (Downer et al., 2015; Herring and Paulson, 2018; Wardazala et al.,, 2013). No cognitive domain demonstrated a consistent association with alcohol use, but all domains exhibited the overall finding, suggesting light to moderate drinking was positively associated with cognitive performance.

Exploring the individual cognitive domains as well as greater analysis of alcohol assessment has updated and added to the findings from the previous reviews/meta-analyses published over a decade ago (Anstey et al., 2009; Peters et al., 2008). Both reported a small number of studies focusing on cognitive decline, whereas 20 studies have been synthesised in this review. This review has developed understanding in the research area, as light and moderate alcohol consumption was associated with better cognitive performance, whereas previous reviews reported no studies with significant findings.

One explanation frequently offered for the improved performance of older light/moderate drinkers relates to alcohol consumption reducing cardiovascular risk factors. Alcohol is considered to have anti-inflammatory properties which is linked to a reduction in hypertension (Panza et al., 2009). Red wine in particular has been associated with positive cardiovascular function, due to antioxidant ingredients which promote an improved lipid profile and vascular tone (Ferrières, 2004). An additional explanation for the better cognitive performance of light/moderate drinkers suggested that alcohol consumption may be representative of moderate health behaviours generally, including diet, sleep, and physical exercise (Hedden & Gabrieli, 2004). These behaviours have positive associations with cognitive ability in old age, and good physical health is likely to have a positive association with cognitive ability (Harris et al., 2006). Lastly, a number of studies highlighted that the non-

drinker groups may represent people who had ceased drinking as well as people who had never consumed alcohol. These two groups may differ, as people who have quit alcohol are reported to have worse health outcomes than lifetime abstainers (Shaper, 2011). Additionally, people who have consumed alcohol at excessive levels earlier in life may experience adverse cognitive consequences which are not explained by the study (Reid et al., 2006).

In general, heavy drinkers were poorly represented in the studies included in this review, and this reflects the lack of research with this group (Monds et al., 2017). Search terms relating to heavy alcohol consumption and alcohol abuse were purposely included in the search strategy in order to capture a broad range of older adult drinkers. Despite this, no study with a specific heavy drinker group or alcoholic sample met the criteria. This is not surprising, due to reduced mortality and increased comorbidity with health problems amongst these groups (Woods et al., 2018). In the studies with a heavier drinking group, all reported small proportions (4.6-8.8%) relative to non-drinkers and other drinker groups. Additionally, the categorisation of drinker groups should be highlighted. Wardazala et al. (2018) described alcohol consumption greater than seven drinks weekly as ‘heavy drinking’, and Zanjani et al. (2013) described the same consumption level as ‘at-risk drinking’, whereas the majority of studies would have categorised this pattern as ‘moderate’ drinking. The QATQS quality assessment did not evaluate the categorisation approach or the proportion of the sample allocated to each group. It is likely that in studies with large non-drinking samples, the drinker groups (light, moderate, etc.) would have been proportionately smaller and not all studies accounted for this in their analyses. Adhering to national guidelines for alcohol consumption to classify categories would reduce bias in authors’ descriptions of drinker groups (Turner and McLellan, 2009), although not every country provides guidelines specific to the older population (e.g. United Kingdom). Defining drinker categories by other methods, such as splitting the sample into quintiles, is likely to generate arbitrary drinking categories particularly as this was done in

samples that reported low levels of alcohol consumption (Ganguli et al., 2005; Hogenkamp et al., 2014). Also, while alcohol consumption in the previous week provides a reliable and valid assessment (Sorroco and Ferrell, 2006), assessing lifetime patterns of consumption may generate more meaningful data about older people's relationship with alcohol (O'Connell, Chin, Cunningham and Lawlor, 2003). Research on the trajectory of alcohol consumption across the lifetime suggests that consumption peaks in early adulthood and reduces later in life (Britton, 2015). Older adults may have engaged in problematic drinking patterns at earlier points in life, and this information is not captured by weekly consumption assessment. Only two studies included lifetime alcohol assessment, the quality of both was rated as 'strong'. While one study reported no remarkable findings (Kalapatupu et al. 2017), another observed that previously consuming more than 28 drinks/week was associated with an adverse executive functioning ability in old age (Reid et al., 2006).

This finding related to old age veterans and was the only diverse sample included in the review. While there were no restrictions relating to samples being institutionalised or in treatment facilities, all 20 studies reported relatively healthy, community-dwelling samples. Participation in research, particularly research involving cognitive assessment, requires a high level of concentration and motivation. Three quarters of the included studies used data from established cohort studies, which provided large sample sizes, and detailed assessment of potential confounding variables, as noted in the quality assessment. Older adults are considered to be a difficult group to recruit and retain in cohort studies, and attrition is associated with increasing age, cognitive impairment, and health factors (Bharma et al., 2008). Similarly, people who misuse substances can be difficult to recruit and retain in research (Barrowclough et al., 2009). As such, longitudinal cohort studies targeting older people, although valuable in understanding the processes that change with age, typically represent the healthiest and most motivated of the older adult population (Odierna and Bero, 2014). This has

been described as the ‘survivor effect’. The studies that did not utilise cohort data focussed on community based older adults’ events or medical clinics to recruit participants, but no study described making additional efforts to include a diverse group of alcohol drinker profiles. Some of the included studies described that alcohol consumption was associated with better education, income, and health status (Corley et al., 2011; Ganguli et al., 2005; Hogenkamp et al., 2014), and this corresponds with previous research (Paschall and Lipton, 2005). This links with the ‘sick quitter’ concept; people who were not consuming alcohol typically had poorer health and were at additional disadvantage relating to cognitive ability in old age. Only two studies further examined the non-drinker group, separating ex-drinkers and lifelong abstainers, and the findings in these studies were mixed, with one study reporting no difference (Kalapatapu et al., 2017) and the other suggesting ex-drinkers who had drank heavily performed poorer than current drinkers who had consistently drank at moderate levels (Reid et al, 2006).

Limitations and strengths

This review has a number of limitations. The studies included often reported low consumption of alcohol by the sample as a whole, and few included participants who were drinking above the recommended guidelines. Restricting the age of inclusion to people over 65 years, may have prevented studies with heavier drinkers from being included. A recent study examining cognition in older heavy drinkers, restricted recruitment to drinkers over 50 years, due to increased risk of mortality in this group (Monds et al., 2017). Additionally, there was variability between studies regarding what constituted a unit/drink of alcohol. This was largely due to differences in national guidelines between countries, but it is acknowledged that comparing studies with different measurements is a limitation (Greenfield and Kerr, 2006). Similarly, while drinker categories were mostly derived from national guidelines, relying on the authors’

definition of what constituted ‘light’/‘moderate’/‘heavy’/‘at risk’ drinking did create some variation between studies and comparison may have been compromised. Furthermore, the inclusion of studies that assessed frequency of alcohol consumption was unwise, as this information did not provide a reliable representation of alcohol use. The variability in how frequency of consumption was categorised between studies also made comparison challenging. Lastly, the grey literature on this research topic was not formally reviewed, and this may have generated additional studies.

While acknowledging the limitations, this review also has a number of strengths. Firstly, the search terms were developed with a combination of scoping searches and analysis of other published reviews in the three key research areas; alcohol, cognition and ageing. This generated a strategic and meaningful search, covering a large number of studies. Additionally, no restrictions were placed on publication date, so the papers included in this review reflect the literature to date in this area. Furthermore, the included studies employed reliable and validated cognitive assessments, sensitive to individual differences. Lastly, while publication bias may have resulted in papers with significant findings dominating this review, three studies reported consistent non-significant results.

Clinical and research implications

The low representation of heavy drinkers over 65 years is indicative of the lack of research devoted to this population. Targeted recruitment of older heavy drinkers may be required to capture this group, as even in large cohort studies, proportionately few people report more than moderate levels of alcohol consumption (i.e. > 7 drinks/units per week). Future research should account for the sociodemographic and health factors that are associated with both maintaining cognitive ability in old age, and alcohol consumption to better explain the ‘sick quitter’ effect. Additionally, as alcohol research frequently attracts media attention, researchers should

consider how to translate the results into media headlines without diluting the nuances of the findings.

As regards clinical implications, despite the positive association of light/moderate alcohol use and cognition reported here, alcohol has a proportionately greater physiological impact on older adults, which should not be underestimated (Menninger, 2002). Alcohol consumption in older adults is associated with negative health outcomes, including increased risk of falls, life limiting diseases, and mortality (Kim, Kisselva and Brenner, 2015; Lusardi et al., 2017; Woods et al., 2018). While currently in the UK there are no specific guidelines for older adults' alcohol consumption, clinicians should continue to assess older adults' drinking habits and provide advice relating to the risks associated with hazardous alcohol use.

Conclusion

The findings of the present review suggest that light to moderate alcohol consumption is associated with better performance on the cognitive domains of memory, executive function, processing speed, and reasoning in older adults. However, the studies included in this review do not reflect older people who are regularly drinking to excess and problematic drinking in the older adult population in the UK is an ongoing public health concern (Drink Well, Age well, 2016). Importantly, the 'non-drinkers' in research may represent two distinct groups: life-long abstainers and quitters, and these groups may have important differences in relation to their cognitive ability in later life. This review has also highlighted that the research literature rarely appropriately represents heavier alcohol drinkers over the age of 65. Further high-quality research is needed to understand the consequences of heavier drinking in the older population.

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The association of alcohol and age-related cognitive change in older people: the English Longitudinal Study of Ageing (ELSA)

Abstract

Maintaining cognitive function in later life is a crucial aspect of healthy ageing. Excessive alcohol consumption is associated with cognitive impairment; however, research exploring older peoples' alcohol use and cognition has suggested a positive association. Many such studies are cross-sectional, and few include people drinking more than 14 units of alcohol/week. This study aims to examine the longitudinal relationship between older peoples' cognitive performance and alcohol consumption using data from the English Longitudinal Study of Ageing. Alcohol consumption and cognition (memory, verbal fluency, processing speed, and global cognition) were assessed on three occasions for 4941 older people with a mean age of 61.9 years (SD=8.38; range 50–91 years) at baseline. Multilevel models for each cognitive domain examined change in cognitive performance associated with alcohol consumption over time. Models were adjusted for sociodemographic factors, physical activity, and mental health. Decline in older adults' performance with increasing age was observed across all cognitive variables. Non-drinkers showed significantly greater decline on all cognitive domains, compared to drinker groups. Heavy drinkers (consuming >14 units/week), demonstrated the least decline in memory and global cognition. This study suggests that alcohol consumption is indicative of better cognitive performance in older people. However, alcohol remains a harmful substance and should be consumed within the national guidelines. These findings have implications for future research in this area, as additional sociodemographic and health factors are likely to contribute to both older peoples' cognitive ability and alcohol consumption.

Keywords: alcohol, drinking, cognition, cognitive decline, health, ageing, late life, older adults

Introduction

An increase in alcohol consumption and misuse among older adults has been reported in recent epidemiological studies, and the physiological, social and cognitive consequences of this have yet to be fully understood (Knott, Combs, Stamikis, 2015). As the population is living longer, understanding the components of positive ageing is fundamental to reducing the future burden on health and social care systems (Deary et al., 2009). Retaining cognitive function is crucial to maintaining independence in later life and has been associated with decreased risk of disability, as well as an increased quality of life in old age (Allerhand, Gale and Deary, 2014; Hedden and Gabrieli, 2004). The present study plans to address the relationship between alcohol consumption, sociodemographic factors, health behaviours and mental health with cognitive performance in adults approaching old age using longitudinal data from the English Longitudinal Study of Ageing (ELSA).

Studies from lifespan cognition have found that there are neurophysiological changes that coincide with the development of cognitive functions across the lifetime. In old age, neurophysiological changes include the shrinkage of neurons, loss of axon myelination, and reduced cerebral blood flow (McDaniel et al., 2008; Resnick et al., 2003). Parallel to this, a progressive decline of some cognitive processes occurs, whereas other processes remain relatively intact (Hedden and Gabrieli, 2004; Park and Reuter-Lorenz, 2009). Little age-associated decline is observed in the 'crystallised' aspects of cognition such as numerical ability, language comprehension, and semantic memory, even into very late life (Fromholt et al., 2003; Park and Reuter-Lorenz, 2006). In contrast, the so-called 'fluid' cognitive abilities exhibit a marked decline as we age (Deary et al., 2009; Hedden and Gabreili, 2004). These include memory - specifically encoding and retrieval of new information, information processing speed, and executive functions, including verbal fluency – the ability to plan,

monitor and generate appropriate response (Burke and McKay, 1997; Nilsson et al., 2014; MacPherson and Dela Salla, 2010). These changes in cognitive performance are distinct from the pathological cognitive difficulties associated with dementia syndromes (Atchley, 1989).

Theories to describe this change in cognition as we age have developed and evolved since the 1950s (See Anderson and Craik, 2017 for a synopsis). The current widely-held view suggests that as we grow older, there is a general slowing in ability to process and utilise information in fluid cognitive processes (Salthouse 1996; 2009). This gradual decline begins around age 30 but becomes more pronounced from age 60 onwards (Schaie, 1996). As a consequence, older adults perform poorer than younger adults on cognitive domains associated with ageing (i.e. those described above).

While cognitive decline is an inevitable part of ageing, the role that sociodemographic characteristics and lifestyle behaviours may have on this decline is a growing area of research (Hedden and Gabrieli, 2004; Deary et al., 2009). Of interest in the present study, is the association of alcohol consumption and cognition in the ageing population. Alcohol adversely affects the neurological systems employed in cognition, emotion, and motivation (Koob, 2014). Chronic, excessive alcohol use throughout life is associated with severe cognitive deficits, including alcohol-related dementia and Korsakoff's syndrome. The features of these impairments are memory problems, reasoning difficulties and executive functioning deficits, including impulse control (Wilson et al., 2012). In cognitively healthy older adults (i.e. those not experiencing dementia syndromes), the findings relating to alcohol and cognitive performance are more mixed. While some cohort studies have reported an association between increased level of alcohol use and aberrant cognition in older adults (Gross et al., 2011; Monds et al., 2017; Sabia et al. 2014), others have reported positive associations (Britton, Singh-Manoux and Marmot, 2004; Moussa et al., 2014). Similar to findings from general physical health research, a U-shaped relationship between alcohol consumption and cognitive

performance has been described. This U-shape describes non-drinkers and heavy drinkers as performing worse than light/ moderate drinkers (i.e. people drinking within recommended national guidelines). 'Non-drinkers' in many studies include people who no longer drink alcohol as well as lifelong abstainers. The reason for abstaining from alcohol may be linked to a health problem, alcohol addiction, or both and may have a confounding influence on the individuals' performance which may not be captured by the study (Brennan, Schutte and Moos, 2010). This describes the 'sick quitter' effect as people who abstain from alcohol typically report worse health (Shaper, 2011).

Some authors have proposed that alcohol drinkers' better performance is due to the positive associations with cardiovascular health (Marques-Vidal et al., 2010). Low levels of alcohol consumption have been linked to a reduction in hypertension due to the anti-inflammatory properties of alcohol (Wright, 2006). However, this explanation is typically offered in the context of a well-balanced diet, and more likely associated with red wine consumption than alcohol generally (Panza, 2009; Sofrizzi, 2010). In a similar way, the positive effects of physical exercise on cognition in old age has been attributed to the associated improvement in cardiovascular function. The vascular benefits of physical exercise in old age is considered to promote cerebral blood flow and maintain brain volume in old age, which is known to play a protective role in the trajectory of age-related cognitive decline (Chang, Lappin, Gabor and Etnier, 2012). Conversely, for cigarette smokers, the chemical contents of tobacco smoke have known toxic effects on the cerebrovascular system (Swan and Lessov-Schlagger, 2007). In research on cognitive ability in older adult populations, smokers regularly perform worse than non-smokers (Bryan and Ward, 2002; Peters, et al., 2008). The combined effect of smoking and alcohol consumption has been linked to enhanced cognitive decline (Sabia et al., 2014).

When assessing cognitive ability in older people depressive symptomology should be considered. The cognitive indicators of depression such as difficulty concentrating, forgetfulness, and slowed processing are often more salient for older people compared to the emotional characteristics of depression (feelings of low mood, sadness, worry, despair, apathy). Many older people present to services with cognitive complaints when they are experiencing depression (Naismith et al., 2012). The transition to old age can be associated with loss experiences – employment status, reduced social network due to bereavement of friends and family members, physical ability, and a high prevalence rate of depression is reported in the older adult population (Rodda, Walker and Carter, 2011). Simultaneously, depressive symptoms are linked with increased alcohol consumption amongst older adults, and so will be accounted for in the present study (Immonen et al., 2011).

Similarly, the sociodemographic factors that have been associated cognitive ability in old age, such as education, employment and socioeconomic status (SES) will be assessed. Education has frequently been reported as having a positive association with cognitive ability in old age, with some authors suggesting this could serve as protection against the rate of cognitive decline (Richards and Deary, 2011; Tucker and Stern, 2011). This potential 'buffer' effect is linked to the theory of cognitive reserve, which suggests that the greater cognitive ability an individual has acquired, the more they can afford to lose before becoming impaired (Stern, 2012). In relation to employment status, retirement for many people marks the beginning of their transition into 'old age' (Haraven and Masaoka, 2011). Retirement potentially reduces an individual's intellectual stimulation and has been associated with a reduction in cognitive performance (Roberts et al., 2010). In the context of older adults, the confounding influence of SES on access to education and health resources throughout life has a strong relationship with older adults' cognitive ability and longevity (Mirowksy and Ross, 2017).

When examining older adults' cognition many studies, both cross-sectional and longitudinal rely on dementia screening tools (e.g. Addenbroke's Cognitive Examination [ACE] (Mathuranath et al., 2000); Mini-Mental State Examination [MMSE] (Folstein, Folstein & McHugh, 1976) to assess cognition. These assessments typically produce ceiling effects in healthy adults and are not sensitive to the subtle change in age-related cognitive decline (Bond et al., 2005; Deary et al., 2009). Research into healthy adults' cognitive decline should incorporate assessment of multiple cognitive domains (Salthouse, 2019). There are fewer studies that assess alcohol's association with specific cognitive domains in older adults. In studies that have, increased alcohol consumption was associated with poorer memory recall, and a decline in executive functioning, reasoning and processing speed (Edelstein, Kritz-Silverstein and Barrett-Connor 1998; Gross et al., 2010; Sabia et al., 2014).

Additionally, heavier alcohol users are underrepresented in cognitive research with the older adult population (Ganguli et al., 2005). Studies reporting the positive association of alcohol often failed to describe a variety of alcohol consumption profiles, typically including only light or moderate drinkers. In some cases, light or moderate alcohol use was the focus of the study, and so heavy drinkers were not recruited (e.g. Herring and Paulson, 2014; Moussa et al., 2015). Other studies failed to recruit enough participants to the heavy alcohol use group, and so excluded them from analysis (Hassing, 2018; Lambert, 2016). By using a nationally representative cohort from ELSA, the present study hopes to adequately capture heavier drinkers (>14 units/week; NICE guidelines [2016]) in the sample.

To summarise, existing research has described a pattern of cognitive decline that occurs from middle age onwards in 'fluid' aspects of cognition. However, the relationship of alcohol with the change in cognitive ageing remains unclear. Using longitudinal data from ELSA, this study will examine the association with repeated measures of alcohol consumption, health behaviours and depression with change in older adults' scores on cognitive domains of

memory, verbal fluency, and processing speed, while adjusting for sociodemographic factors. Specific aims of the study include:

i) To assess age-related cognitive change in the domains of memory, verbal fluency and processing speed. It is expected that there will be a decline in performance with time.

ii) To explore the relationship between alcohol consumption and older adults' cognitive performance, measured at three timepoints (wave 1, 4 and 5). Increased alcohol consumption is expected to be associated with a decrease in cognitive performance across all domains.

iii) To explore the association of health behaviours –not smoking and participating in physical exercise, with cognitive functioning in older age. It is expected that smoking will be negative associated with cognitive performance whereas regular exercise will be positively associated with better cognitive performance.

iv) To explore the role of depression in cognitive function in older adults. Depressive symptoms are expected to be negatively associated with performance on cognitive tasks.

Methods

Data

The present study used data from the English Longitudinal Study of Ageing (ELSA) – Wave 0 (1998, 1999, 2001), Wave 1 (2002/2003), Wave 4 (2008/2009) and Wave 5 (2010/2011). ELSA is a prospective and nationally representative cohort of men and women over 50 years of age, living in England (Steptoe et al., 2012). The original ELSA sample were recruited from participants who responded to the Health Survey for England (HSE) in the years 1998, 1999, and 2001, and were aged 50 years or over when ELSA began in 2002. The HSE data for the respective years became Wave 0 of ELSA and is available for analysis with the ELSA dataset.

HSE has been running annually since 1991, collecting data in relation to physical and mental health, social care, and lifestyle behaviours of people in England. HSE recruited participants by sending out questionnaires for households to complete and return. Responses to the HSE are used to inform health policy and improve health services across England. Addresses were selected at random from all private addresses in England. The first wave of ELSA was conducted in 2002 with a sample size of 12,099 participants (11,391 of whom had been participants in HSE, and 708 were partners of those who completed HSE and were eligible and willing to participate in ELSA). See Figure 1. for further details.

Ethical considerations

ELSA was conducted in accordance with the Declaration of Helsinki. Ethical approval for the ELSA study was granted by the London Multicentre Research Ethics Committee (MREC/01/2/91) and informed consent was obtained from all participants. The present study has been conducted in accordance with the guidelines of UK Data Service (See Appendix D.).

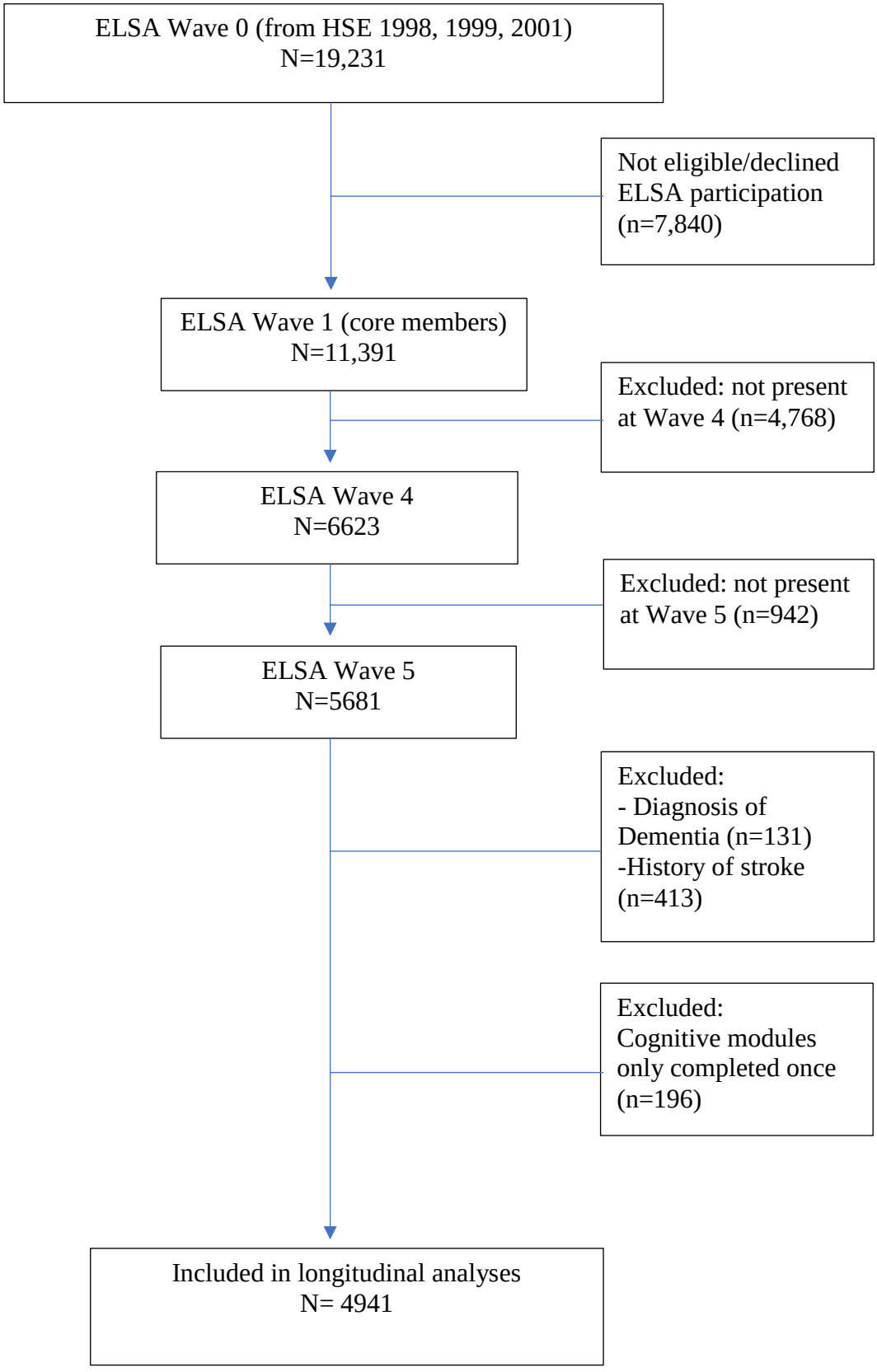

Figure 2. Flowchart illustrating the sample selection. Flowchart illustrating sample selection. (ELSA, English Longitudinal Study of Ageing; HSE, Health Survey for England)

Cognitive variables

The cognitive domains of memory, verbal fluency, and processing speed were assessed at Wave 1, 4 and 5. (Cognition was not assessed in HSE, which formed Wave 0 of ELSA.)

Memory was assessed using the immediate and delayed recall of a 10-word learning task. Participants were verbally presented with ten common nouns, at a rate of one word every 2 seconds, using a computer. There are 4 versions of the word list; a different one is used at each wave. Directly after this, participants recalled as many words as possible, which was their score for immediate memory. Participants continued to complete the remainder of the cognitive subtests. When completed (approximately 15 minutes after the initial Word List task), participants were asked to recall the word list from memory. This was the delayed memory score. Participants scored '1' for each word remembered correctly. Scores for immediate and delayed memory were added together to create the memory variable (ranging from 0-20 in the sample).

Verbal fluency was assessed using a naming task. This task required participants to name as many animals as possible in one minute. Each correctly mentioned animal received a score of '1', with scores ranging from 0 to 54 in the sample.

Processing speed was assessed using a letter cancellation task. In this task, participants were presented with a grid of 780 letters, and attempted to cross out as many of the 65 target letters ('P' and 'W') as possible in 1 minute. Total number of target letters crossed out formed the score for processing speed (ranging from 0-63 in the sample).

Global cognition was obtained by standardising the scores for each of the cognitive domains into z-scores (a mean of 0 and a standard deviation of 1) and adding them together.

Alcohol

ELSA includes questions relating to alcohol consumption at all waves, but these are not consistent across the study. In Wave 0, a detailed assessment of alcohol consumption was completed. Participants were asked how many drinks they consumed in the past week relating to wine, beer, spirits, alcopops, and sherry. However, in Wave 1, participants were only asked if '*since the last time we interviewed you {date given}, have you changed your drinking habits?*' and if they responded *yes*, participants were asked to clarify '*Do you now drink a little/ a lot less or a little/ a lot more*?'. This does not provide an accurate account of the amount of alcohol consumed. For this reason, data relating to alcohol consumption was fed forward from Wave 0 into Wave 1. This has been done with other variables in the dataset (e.g. ethnicity and employment), and in other studies using ELSA's alcohol data (Holdsworth et al., 2017). In Wave 2 and Wave 3 alcohol consumption items were restricted to the heaviest day of drinking. In Wave 4 and Wave 5 participants were asked the number of glasses of wine/pints of beer/measures of spirits they had consumed in the last week. Participants were asked to consider sherry as wine and alcohol-pops as spirits. As a consequence of the variability in alcohol assessment across the waves, the analysis in the present study is limited to Wave 1 (with alcohol data brought forward from Wave 0), Wave 4, and Wave 5. The number of drinks from the included waves were recalculated into alcohol units, using the NHS alcohol unit calculator (See https://www.nhs.uk/live-well/alcohol-support/calculating-alcohol-units/#calculating-units) as in previous studies using ELSA data (Ipparraguire, 2015).

Frequency of alcohol consumption was assessed by asking participants who drank alcohol how often they drink. Response options were: five/six days a week; three/four days a

week; once or twice a week; once or twice a month; once every couple of months; once or twice a year; not at all in the last 12 months.

Participants were categorised into 4 alcohol consumption categories: 'non-drinker'; 'light' (up to 7 units/week); 'moderate' (>7 units and up to 14 units/week); and 'heavy' (> 14 units/week). Participants who had not consumed alcohol in the past 12 months were categorised as non-drinkers.

Sociodemographic variables

Age, sex and relationship status ('single', 'married', 'divorced and separated', and 'widowed') was recorded for all participants.

Employment status

Participants were categorised as: 'economically inactive' (in receipt of job seeker or disability benefits); 'caring for family members'; 'retired'; and 'in employment' or 'self-employed'. For the present study 'in employment' and 'self-employed' were re-categorised together as 'in employment'.

Childhood socio-economic status

A rudimentary calculation of childhood socio-economic status was derived from the professions of the participants' fathers from when the participants were 14 years of age. These professions were coded into 15 categories in the ELSA data and these have been further categorised into 'high' (business owner, professional or technical, and administrative/ clerical professions), 'intermediate' (trade and service-related professions), and 'low' (manual/casual occupations, as well as unemployed) as in other ELSA studies (Zaninotto et al., 2017).

Table 1. Participant characteristics (N=4941)

	Wave 1 n (%)	Wave 4 n (%)	Wave 5 n (%)
Age (in years)			
Mean (SD), range	61.96 (8.38), 50- 91	68.21 (8.52), 56-96	70.32 (8.73), 58-98
Sex			
Male	2142 (43.35%)	-	-
Female	2799 (56.65%)	-	-
Marital status			
Single	257 (5.20%)	-	-
Married & remarried	3442 (69.68%)	-	-
Separated & divorced	593 (12.00%)	-	-
Widowed	648 (13.10%)	-	-
Employment status			
Economically inactive	290 (5.87%)	-	-
Caring for family members	468 (9.48%)	-	-
Retired	2145 (43.43%)	-	-
Employed	2036 (41.22%)	-	-
Childhood SES			
Low	1579 (32.25%)	-	-
Intermediate	1578 (32.23%)	-	-
High	1739 (35.52%)	-	-
Education			
No qualifications	1579 (31.96%)	-	-
High school qualifications/ equivalent	2616 (52.94%)	-	-
Degree/ higher	746 (15.10%)	-	-

Table 1. Participant characteristics (N=4941) (continued)

	Wave 1 n (%)	Wave 4 n (%)	Wave 5 n (%)
Current SES (wealth in quintiles)			
1st	970 (20.00%)	-	-
2nd	970 (20.00%)	-	-
3rd	970 (20.00%)	-	-
4th	970 (20.00%)	-	-
5th	970 (20.00%)	-	-
Health variables (time co-varying)			
Smoker status			
Current	772 (15.62%)	573 (11.60%)	523 (10.58%)
Ex-smoker	2252 (45.58%)	2459 (49.77%)	2,614 (52.90%)
Never smoked	1917 (38.80%)	1909 (38.64%)	1804 (36.51%)
Physical activity			
More once a week	1593(32.2%)	1743(35.2%)	1951 (39.4%)
Less than once a week	3348(67.8%)	3198 (64.7%)	2990 (60.5%)
Depression			
Not depressed CES-D score >4	4246 (87.1%)	4262 (87.2%)	4187 (86.40%)
Depressed CES-D score <4	627 (12.9%)	624 (12.8%)	660 (13.60%)
Alcohol consumption			
Non-drinker	381 (7.71%)	990 (18.62%)	874(18.08%)
Light drinker	2294 (46.43%)	2090 (43.24%)	2177 (45.03%)
Moderate drinker	928 (18.78%)	701(14.50%)	681(14.08%)
Heavy drinker	1338 (27.08%)	1142(23.63%)	1103(22.81%)

Education

In ELSA, participants were asked to state the highest level of education they had achieved, ranging from no formal secondary school qualifications (GCSE/A-Levels equivalents) at the lowest level to the highest level being an NVQ4/ university degree. For the purpose of this study, education was categorised into 3 levels; 'No qualifications' (those who had not completed secondary school); 'Secondary school qualifications' (GSCE/A-Level equivalents); and 'Degree or higher', as no detail on postgraduate education is collected in ELSA.

Wealth/SES

The most accurate method of describing socio-economic status in ELSA has been described as summing savings, investments, property and business assets, and debt, exclusive of pension wealth (Banks et al., 2009). A categorical variable was derived from this data to create quintiles of wealth in the current sample.

Health variables

Smoking

Participants were categorised as current, never, or ex-smokers at Wave 1, 4 and 5.

Physical activity

Participants were asked how frequently they engaged in moderate/vigorous exercise: more than once a week, once a week, one to 3 times per month, or hardly ever. This was recoded as a dichotomous variable for Wave 1, 4 and 5 based on whether or not participants took part in moderate to vigorous exercise once a week or more (Bostock and Steptoe, 2013).

Depression

The 8-item version of the Center for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977) was used to assess participants' overall mood and depressive symptomology (Appendix E). This abbreviated version has demonstrated good internal validity and reliability of assessing depressive symptoms in the older adult population (Karim Weisz, Bibi, and Rehman, 2015; Turvey, Wallace, and Hogg, 1999). Participants responded 'yes' or 'no' to 8 statements corresponding to mood. Items include: '*during the past week, have you felt lonely?*' and '*during much of the past week, have you enjoyed your life?*' Items were scored 1 for 'yes' and 0 for 'no'. Negatively coded items were recoded so that a total score for the CES-D could be calculated, with a higher score representing greater depressive feelings. A categorical variable was derived from the CES-D total score at each wave; participants who scored greater than 4 were categorised as 'depressed', to represent the group of people experiencing elevated depressive symptoms. This cut-off/categorisation was made to account for any association depression may have with participants' performance on cognitive measures and has been used in previous studies utilising the CES-D (Hamer, Batty and Kivimaki, 2012; Zaninotto et al., 2018).

Data analysis

The overall aim of this study was to explore within and between person variance of cognitive performance as people age and how alcohol consumption, sociodemographic and health covariates influence this. The analytic sample included all participants who were present for Wave 1, 4 and 5 and had completed the cognitive module variables on at least two occasions, in order to capture change over time. Participants with cognitive data for less than two waves

were excluded (n=196). Participants who reported having a diagnosis of dementia (n=131) or having experienced a stroke were also excluded (n=413) due to the impact this may have had on cognitive performance. Respondents who either left ELSA or were recruited in a refreshment sample were not included in the present study.

Multi-level modelling was selected rather than growth curve modelling as it can effectively separate the within-person change (Curran and Bauer, 2011). The analysis offered information about the participants' initial cognitive performance (intercept) and the trajectory of change in cognitive performance (slope) during the 8-year time period. We modelled how cognition varied across Wave 1 (2002/2003), Wave 4 (2008/2009) and Wave 5 (2010/2011). Four two-level mixed effects models were designed for the analysis, one for each of the three cognitive domains – memory, verbal fluency and processing speed, and one for the composite global cognition score. Level 1 described change at an individual level, the within-person change in cognitive function over time. Level 2 represented the group level, and the between-person change in cognitive performance with time.

Models were fitted in a hierarchical approach with predictor variables added gradually, so that the contribution of each predictor variable could be observed. For Model 1, age at baseline was included in the model, to ascertain if there was a change in cognitive performance with age. Following this, for Model 2 alcohol consumption was added to the model, to illustrate the relationship between cognitive performance, age and alcohol consumption. Next, for Model 3 the sociodemographic variables (gender, marital status, employment status, education, childhood and current SES) were added. All sociodemographic variables were added as time invariant predictors. Model 4 included health variables (smoking, physical exercise) identified as having an association with cognitive performance in later life. Lastly, the mental health variable (CES-D depression categorisation) was fitted to describe the final model, Model 5. There was a reduction in sample size from Model 2 to Model 3 in all of the cognitive domain

analysis. This is due to participants missing data on demographic variables (n=135). This change was considered to be a minimal difference and did not warrant further adjustment.

Memory, verbal fluency, processing speed and global cognition were modelled separately, but followed the same modelling strategy. Results from the cognitive domains are displayed in tables with the models nested from left to right. The estimates of the variance within-individual and between-individuals are listed in the lower part of the table, with model fit and intraclass correlation. Assessment of model fit displaying the effect of adding additional variables and has a $\chi 2$ distribution with the number of added variables equals the number of degrees of freedom.

All analyses were completed using Stata 15.1.

Table 2. *Cross tabulations of sociodemographic and health variables with alcohol consumption*

	Non-drinkers n(%)			**Light drinkers n(%)**			**Moderate drinkers n(%)**			**Heavy drinkers n(%)**		
	Wave			Wave			Wave			Wave		
	1 n=381	4 n=900	5 n=874	1 N=2294	4 n=2090	5 n=2117	1 n=928	4 n=701	5 n=681	1 n=1338	4 n=1142	5 n=1103
Age												
Mean (SD)	64.27 (8.75)	69.57 (9.46)	73.22 (9.90)	62.61 (8.54)	68.98 (8.61)	70.71 (8.67)	61.19 (8.22)	66.44 (7.82)	68.85 (7.82)	60.71 (7.84)	66.75 (7.64)	68.05 (7.47)
Sex												
Male	120 (31.50%)	324 (36.00%)	294 (33.64%)	696 (30.34%)	715 (34.21%)	764 (35.09%)	422 (45.47%)	321 (45.79%)	333 (48.90%)	904 (67.56%)	743 (65.06%)	714 (64.73%)
Female	261 (68.50%)	576 (64.00%)	580 (66.36%)	1598 (69.69%)	1375 (65.79%)	1413 (64.91%)	506 (54.53%)	380 (54.21%)	348 (51.10%)	434 (31.44%)	399 (34.94%)	389 (35.27%)
Marital status												
Single	26 (6.82%)	63 (7.00%)	63 (7.21%)	119 (5.19%%)	94 (4.50%)	99 (4.55%)	37 (3.99%)	32 (4.56%)	25 (3.67%)	75 (5.61%)	64 (5.61%)	66 (5.00%)
Married	226 (59.32%)	511 (56.78%)	501 (57.44%)	547 (67.44%)	1448 (69.28%)	1510 (69.36%)	689 (74.33%)	538 (76.75%)	519 (76.21%)	980 (73.24%)	866 (75.90%)	831 (75.41%)
Divorced & separated	47 (12.34%)	153 (17.00%)	124 (14.19%)	281 (12.25%)	244 (11.67%)	266 (12.22%)	106 (11.43%)	66 (9.42%)	72 (10.57%)	159 (11.88%)	118 (10.43%)	122 (11.07%)
Widowed	82 (21.52%)	173 (19.22%)	185 (21.17%)	347 (15.13%)	304 (14.55%)	302 (13.87%)	95 (10.25%)	65 (9.27%)	65 (9.54%)	124 (9.27%)	93 (8.15%)	83 (7.53%)

Table 2. *Cross tabulations of sociodemographic and health variables with alcohol consumption (continued)*

	Non-drinkers n(%)			**Light drinkers n(%)**			**Moderate drinkers n(%)**			**Heavy drinkers n(%)**		
	Wave			Wave			Wave			Wave		
	1 n=381	4 n=900	5 n=874	1 N=2294	4 n=2090	5 n=2117	1 n=928	4 n=701	5 n=681	1 n=1338	4 n=1142	5 n=1103
Employment Status												
Economically inactive	39 (10.24%)	99 (11.00%)	89 (10.18%)	133 (5.80%)	100 (4.79%)	110 (5.05%)	39 (4.20%)	34 (4.85%)	30 (4.41%)	79 (5.91%)	52 (4.56%)	59 (5.35%)
Caring for family members	55 (14.44%)	103 (11.44%)	103 (11.78%)	257 (11.21%)	223(10.67%)	234 (10.75%)	81 (8.73%)	55 (7.85%)	55 (8.09%)	75 (5.61%)	70 (6.13%)	66 (5.99%)
Retired	192 (50.39%)	398 (44.22%)	446 (51.03%)	1052 (45.88%)	970(46.43%)	975 (44.79%)	377 (40.62%)	267 (38.09%)	268 (39.41%)	524 (39.19%)	464 (40.67%)	409 (37.11%)
Employed	95 (24.93%)	300 (33.33%)	236 (27.00%)	851 (37.11%)	796 (38.10%)	858 (39.41%)	431 (46.44%)	345 (49.22%)	327 (48.09%)	659 (49.29)	555 (48.64%)	568 (51.54%)
Education												
No qualifications	191 (50.13%)	419 (46.56%)	440 (50.34%)	842 (36.70%)	735 (35.17%)	751 (34.50%)	228 (24.57%)	157 (22.40%)	161 (23.64%)	318 (23.77%)	224 (19.61%)	192 (17.41%)
High school qualifications	161 (42.26%)	399 (44.33%)	365 (41.76%)	1204 (52.48%)	1146 (54.83%)	1193 (54.80%)	525 (56.57%)	408 (58.20%)	396 (58.15%)	726 (54.26%)	611 (53.50%)	604 (54.76)
Degree or higher	29 (7.61%)	82 (9.11%)	69 (7.89%)	248 (10.81%)	209 (10.00%)	233 (10.70%)	175 (18.86%)	136 (19.40%)	124 (18.21%)	294 (21.97%)	307 (26.88%)	307 (27.83%)

Table 2. *Cross tabulations of sociodemographic and health variables with alcohol consumption (continued)*

	Non-drinkers n(%)			**Light drinkers n(%)**			**Moderate drinkers n(%)**			**Heavy drinkers n(%)**		
	Wave			Wave			Wave			Wave		
	1 n=381	4 n=900	5 n=874	1 N=2294	4 n=2090	5 n=2117	1 n=928	4 n=701	5 n=681	1 n=1338	4 n=1142	5 n=1103
Childhood SES												
Low	143 (37.73%)	345 (38.90%)	340 (39.35%)	797 (35.14%)	713 (34.48%)	726 (33.70%)	267 (29.05%)	194 (27.79%)	209 (30.92%)	372 (27.97%)	291 (25.59%)	270 (24.57%)
Inter-mediate	129 (34.04%)	286 (32.24%)	285 (32.99%)	728 (32.10%)	682 (32.98%)	732 (33.98%)	285 (31.03%)	222 (31.81%)	195 (28.85%)	436 (32.78%)	355 (31.22%)	329 (29.94%)
High	107 (28.23%)	256 (28.86%)	239 (27.66%)	743 (32.76%)	673 (32.54%)	696 (32.31%)	376 (39.93%)	282 (40.40%)	272 (40.24%)	522 (39.25%)	491 (43.18%)	500 (45.50%)
Current SES (wealth in quintiles)												
1st	133 (35.95%)	315 (36.00%)	300 (34.97%)	511 (22.61%)	426 (20.71%)	454 (21.23%)	130 (14.36%)	92 (13.29%)	77 (11.49%)	196 (14.90%)	115 (10.28%)	123 (11.40%)
2nd	81 (21.89%)	195 (22.29%)	196 (22.84%)	496 (21.95%)	469 (22.80%)	477 (22.31%)	173 (19.12%)	119 (17.20%)	114 (17.01%)	220 (16.73%)	172 (15.27%)	153 (14.18%)
3rd	66 (17.84%)	160 (18.29%)	160 (18.65%)	453 (20.04%)	443 (21.54%)	447 (20.91%)	189 (20.88%)	150 (21.68%)	158 (23.58%)	262 (19.92%)	189 (16.89%)	189 (17.52%)
4th	46 (12.43%)	99 (11.31%)	108 (12.59%)	426 (18.85%)	404 (19.64%)	409 (19.13%)	214 (23.65%)	177 (25.58%)	154 (22.99%)	284 (21.60%)	274 (14.49%)	272 (25.21%)
5th	44 (11.89%)	106 (12.11%)	94 (10.96%)	374 (16.55%)	315 (15.31%)	351 (16.42%)	199 (21.99%)	154 (22.25%)	167 (24.93%)	353 (26.84%)	369 (32.98%)	342 (31.70%)

Table 2. *Cross tabulations of sociodemographic and health variables with alcohol consumption*

	Non-drinkers n(%)			**Light drinkers n(%)**			**Moderate drinkers n(%)**			**Heavy drinkers n(%)**		
	Wave			Wave			Wave			Wave		
	1 n=381	4 n=900	5 n=874	1 N=2294	4 n=2090	5 n=2117	1 n=928	4 n=701	5 n=681	1 n=1338	4 n=1142	5 n=1103
Smoker status												
Current	65 (17.06%)	149 (16.56%)	128 (14.65%)	354 (15.04%)	241 (11.53%)	233 (10.70%)	117 (12.61%)	60 (8.56%)	51 (7.49%)	245 (18.31%)	111 (9.72%)	100 (9.07%)
Ex-smoker	135 (35.42%)	405 (45.00%)	431 (49.31%)	940 (40.98%)	945 (45.22%)	1046 (48.05%)	451 (48.60%)	354 (50.50%)	380 (55.80%)	726 (54.26%)	697 (61.03%)	695 (63.01%)
Never smoked	181 (47.51%)	346 (38.44%)	315 (36.04%)	1009 (43.98%)	904 (43.25%)	898 (41.25%)	360 (38.79%)	287 (40.94%)	250 (36.71%)	367 (27.43%)	334 (29.25%)	308 (27.92%
Physical Activity												
< once a week	222 (58.27%)	472 (52.44%)	398 (44.51%)	1478 (64.42%)	1261 (60.33%)	1291 (59.30%)	669 (72.09%)	507 (72.33%)	457 (67.11%)	979 (73.17%)	886 (77.58%)	789 (71.53%)
> once a week	159 (42.73%)	428 (47.56%)	485 (55.49%)	816 (35.57%)	829 (39.67%)	886 (40.70%)	259 (27.91%)	194 (27.67%)	224 (32.89%)	359 (26.83%)	256 (22.42%)	314 (28.47%)
Depression (CES-D score)												
Not depressed (>4)	282 (75.81%)	686 (78.67%)	621 (75.82%)	1945 (85.83%)	1790 (86.22%)	1863 (86.45%)	821 (89.43%)	635 (91.10%)	616 (90.72%)	1198 (91.03%)	1057 (93.29%)	1000 (91.83%)
Depressed (<4)	90 (24.19%)	186 (21.33%)	198 (24.18%)	321 (14.17%)	286 (13.78%)	292 (13.55%)	98 (10.66%)	62 (8.90%)	63 (9.28%)	118 (8.97%)	76 (6.71%)	89 (8.17%)

Results

Sample characteristics

The final sample (N=4941) had a mean age of 61.96 years (std.= 8.38 years; range 50–91 years) at baseline and was 56.65% female. Table 1 displays the sociodemographic, health, mental health and alcohol consumption characteristics of the sample. As sociodemographic variables were modelled as time invariant, only the sociodemographic details provided at baseline are included, whereas the characteristics for alcohol consumption, health and depression variables at all three waves are shown.

Married participants make up 69% of the sample. A large proportion of the sample was either in employment (41.22%) or retired from employment (43.43%). For childhood SES, the sample was split relatively evenly across low, intermediate and high categories. Over half the sample had achieved a high school education, with only 15.1% completing third level qualifications. The number of current smokers reduced across the three waves. Physical activity showed a gradual reduction from Wave 1 (67.8%) through to Wave 5 (60.5%), suggesting that participants are becoming less active as they age. There was little variation in the number of participants categorised as depressed across the three waves, ranging from 12.8-13.6%. For alcohol consumption, there was a general decrease in alcohol consumption from Wave 1 to Wave 5. The number of non-drinkers increased by a substantial amount between Wave 1 and Wave 4, from 7.7% to 18.6%, and a slight drop in Wave 5 (18.08%). In all waves, light drinkers made up over 40% of the sample. The next largest group was heavy drinkers, who made up approximately 20% of the sample in each wave. Details of alcohol consumption at the three waves in relation to participant characteristics are included in Table 2. Non-drinkers tended to be older than other drinker groups, and heavy drinkers in the sample reported higher education and higher current SES. The mean scores for cognitive variables at each wave are displayed in Table 3.

Table 3. *Mean scores for cognitive variables*

	Memory Mean (SD)			**Verbal fluency Mean (SD**			**Processing speed Mean (SD)**			**Global cognition Mean (SD)**		
	Wave			Wave			Wave			Wave		
	1	4	5	1	4	5	1	4	5	1	4	5
Sex												
Male	10.24(3.15)	10.19(3.26)	10.05(3.45)	21.26(6.26)	21.42(6.70)	21.03(6.61)	18.92(5.41)	18.06(4.83)	18.64(5.13)	-.14(2.12)	-.19(2.16)	-.10(2.12)
Female	10.63(3.19)	10.80(3.48)	10.50(3.71)	20.51(6.02)	20.71(6.40)	20.37(6.71)	20.47(5.77)	19.75(5.53)	19.25(5.49)	.13(2.12)	.17(2.28)	.28(2.19)
Marital status												
Single	10.00(3.50)	10.16(3.53)	9.95(3.9)	20.38(6.23)	20.70(7.41)	19.95(7.73)	19.53(5.41)	18.68(4.64)	18.05(5.24)	-.12(2.26)	-.18(2.33)	-.08(2.26)
Married	10.62(3.13)	10.78(3.30)	10.63(3.44)	21.21(6.12)	21.50(6.51)	21.23(6.49)	19.92(5.66)	19.15(5.19)	18.72(5.34)	.14(2.10)	.18(2.16)	.27(2.11)
Divorced & separated	10.59(3.09)	10.77(3.35)	10.30(3.51)	20.78(6.45)	20.98(6.50)	20.65(6.57)	20.04(5.32)	19.40(5.16)	18.89(5.38)	.07(2.11)	.14(2.22)	.24(2.08)
Widowed	9.47(3.23)	9.13(3.50)	8.70(3.90)	19.12(5.60)	18.71(6.12)	17.93(6.61)	19.11(6.02)	18.00(6.08)	17.52(5.65)	-.69(2.09)	-.94(2.35)	-.82(2.27)
Employment Status												
Economically inactive	11.19(3.03)	11.47(3.15)	11.41(3.21)	19.65(6.24)	19.92(5.97)	20.30(6.38)	18.86(5.32)	18.31(5.64)	17.35(5.11)	-.48(2.02)	-.41(2.08)	-.31(2.03)
Caring for family members	10.07(3.08)	10.04(3.35)	9.65(3.55)	20.38(6.14)	20.41(6.72)	20.03(6.43)	20.55(6.50)	19.84(6.08)	19.63(6.12)	.09(2.20)	.15(2.48)	.32(2.31)
Retired	10.53(3.23)	10.80(3.63)	10.33(3.84)	19.92(5.90	19.87(6.48)	19.17(6.68)	19.01(5.50)	18.05(5.21)	17.39(5.22)	-.48(2.05)	-.60(2.22)	-.55(2.15)
Employed	9.80(3.16)	9.66(3.35)	9.34(3.61)	22.09(6.16)	22.54(6.40)	22.44(6.34)	20.59(5.55)	19.93(4.98)	19.66(5.15)	.59(2.05)	.69(2.01)	.80(1.94)

Table 3. *Mean scores for cognitive variables (continued)*

	Memory Mean (SD			**Verbal fluency Mean (SD)**			**Processing speed Mean (SD)**			**Global cognition Mean (SD)**		
	Wave			Wave			Wave			Wave		
	1	4	5	1	4	5	1	4	5	1	4	5
Childhood SES				1								
Low	9.94(3.52)	9.97(3.47)	9.79(3.54)	9.84(6.04)	19.92(6.51)	19.65(6.56)	19.11(5.47)	18.40(5.20)	18.09(5.67)	-.44(2.10)	-.42(2.23)	-.26(2.17)
Inter-mediate	10.30(3.07)	10.47(3.22)	10.17(3.45)	20.58(5.88)	20.96(6.40)	20.47(6.49)	19.67(5.55)	18.84(5.25)	18.26(5.41)	-.10(2.07)	-.06(2.15)	-.01(2.14)
High	11.07(3.19)	11.10(3.40)	10.89(3.69)	22.01(6.26)	22.08(6.61)	21.79(6.78)	20.57(5.86)	19.72(5.38)	19.22(5.45)	.54(2.10)	.47(2.23)	.57(2.12)
Current SES (wealth in quintiles)												
1st	9.45(3.23)	9.34(3.40)	9.17(3.63)	18.84(5.98)	19.00(6.07)	18.64(6.38)	18.77(5.66)	18.31(5.85)	17.59(5.37)	-.81(2.13)	-.79(2.22)	-.65(2.15)
2nd	10.21(3.14)	10.14(3.30)	9.79(3.55)	20.39(5.82)	20.21(6.51)	19.99(6.55)	19.33(5.29)	18.35(4.93)	18.01(5.10)	-.23(2.04)	-.37(2.18)	-.21(2.09)
3rd	10.43(3.20)	10.54(3.38)	10.43(3.51)	21.01(6.27)	21.03(6.38)	20.92(6.62)	19.97(5.50)	19.14(5.20)	18.77(5.75)	-.05(2.12)	-.10(2.14)	.19(2.17)
4th	10.95(3.05)	11.09(3.33)	10.90(3.47)	21.69(5.90)	21.76(6.60)	21.37(6.61)	20.12(5.56)	19.29(4.65)	18.93(5.17)	.36(1.96)	.33(2.12)	.44(2.05)
5th	11.17(3.01)	11.48(3.16)	11.18(3.49)	22.20(6.13)	22.70(6.61)	22.19(6.65)	20.60(5.84)	19.94(5.69)	19.35(5.39)	.61(2.02)	.73(2.16)	.72(2.09)
Education												
No qualifications	9.16(3.12)	9.09(3.23)	8.82(3.48)	18.52(5.43)	18.46(5.82)	17.98(6.08)	18.53(5.53)	17.77(5.46)	17.33(5.33)	-.99(1.98)	-1.03(2.08)	-.89(2.02)
High school qualifications	10.80(3.02)	10.94(3.22)	10.73(3.40)	21.36(5.94)	21.68(6.42)	21.35(6.45)	21.12(5.47)	19.35(5.15)	18.86(5.24)	.26(1.98)	.30(2.10)	.37(2.04)
Degree or higher	12.02(2.83)	12.15(3.25)	11.96(3.43)	23.94(6.43)	24.13(6.66)	23.90(6.63)	21.36(6.06)	20.39(4.97)	20.00(5.59)	1.29(.98)	1.20(2.06)	1.30(2.02)

Table 3. *Mean scores for cognitive variables (continued)*

	Memory Mean (SD			**Verbal fluency Mean (SD)**			**Processing speed Mean (SD)**			**Global cognition Mean (SD)**		
	Wave			Wave			Wave			Wave		
	1	4	5	1	4	5	1	4	5	1	4	5
Smoker status												
Current	10.40(3.28)	10.23(3.28)	10.19(3.45)	20.33(6.47)	20.35(6.43)	19.83(6.54)	19.64(5.52)	18.72(4.54)	18.23(5.25)	-.12(2.23)	-.21(2.15)	-.13(2.06)
Ex-smoker	10.39(3.16)	10.42(3.39)	10.19(3.59)	21.07(6.13)	21.05(6.56)	20.68(6.70)	19.78(5.92)	18.85(5.31)	18.33(5.31)	.02(2.14)	-.04(2.23)	.04(2.15)
Never smoked	10.56(3.16)	10.77(3.44)	10.47(3.65)	20.78(6.00)	21.20(6.61)	20.87(6.66)	19.88(5.41)	19.31(5.22)	18.97(5.54)	.06(2.07)	.16(2.26)	.28(2.21)
Physical Activity												
< once a week	10.66(3.12)	10.96(3.24)	10.90(3.36)	21.38(6.10)	21.86(6.51)	21.65(6.45)	19.98(5.45)	19.34(5.08)	19.08(5.04)	.19(2.07)	.32(2.13)	.47(2.01)
> once a week	10.02(3.27)	9.74(3.54)	9.38(3.76)	19.69(6.10)	19.48(6.41)	19.12(6.74)	19.41(5.98)	18.33(5.64)	17.72(5.83)	-.38(2.19)	-.55(2.31)	-.46(2.29)
Depression (CES-D score)												
Not depressed (>4)	10.56(3.14)	10.69(3.38)	10.51(3.51)	21.05(6.12)	21.25(6.54)	20.93(6.65)	19.90(5.70)	19.09(5.13)	18.76(5.37)	-.49(2.14)	.11(2.19)	.22(2.14)
Depressed (<4)	9.86(3.40)	9.533.35)	9.09(3.90)	19.51(6.02)	19.65(6.48)	19.07(6.61)	19.19(5.23)	18.54(6.33)	17.18(5.44)	.09(2.11)	-.58(2.38)	-.60(2.23)
Alcohol Consumption												
Non-drinker	9.51(3.35)	9.40(3.48)	8.68(3.88)	18.76(0.07)	18.92(6.42)	18.14(6.81)	18.38(5.46)	18.21(5.57)	17.34(5.77)	-.83(2.19)	-.74(2.36)	-.83(2.33)
Light drinker	10.35(3.14)	9.57(3.49)	10.19(3.47)	20.47(6.06)	20.74(6.30)	20.37(6.50)	19.98(5.76)	18.94(5.41)	18.60(5.27)	-.05(2.10)	-.09(2.19)	.04(2.09)
Moderate drinker	10.75(3.15)	10.38(3.41)	10.99(3.43)	21.52(6.15)	22.13(6.32)	21.83(6.27)	20.00(5.47)	20.01(5.19)	19.28(5.53)	.24(2.09)	.53(2.08)	.57(2.12)
Heavy drinker	10.72(3.17)	11.05(3.19)	11.30(3.35)	21.58(6.09)	22.55(6.83)	21.82(6.67)	19.75(5.64)	19.22(4.89)	18.85(5.17)	.20(2.11)	.49(2.11)	.64(2.00)

Multilevel model analysis

Multi-level models are special regression analyses that allow for two kinds of effects to be assessed: fixed effects, and random effects. The fixed effects relate to the intercepts and slopes used to describe the sample as a whole, as in regression analysis. This is the between-person variance. The random effects account for the intercepts and slopes that can vary across subgroups of the sample, in this study the individual participants' cognitive performance as they age and describes the within-person variance. Results for the multilevel model analysis are displayed separately for memory (Table 4.) verbal fluency (Table 5.), processing speed (Table 6.) and global cognition (Table 7.). Across the four modelling strategies, small proportions of within-person variance were accounted for in the fully adjusted models. For between-person variance, the amount explained by the final models was typically <1%. For memory, the fully adjusted model (Model 4.5) accounted for 23.51% of the overall within-person variance, and 0.96% of the between-person variance. In verbal fluency, 17.13% of the within-person variance, and 0.67% of the between-person variance was explained by the final model (Model 5.5). The fully adjusted model for processing speed (Model 6.5) accounted for 12.85% of the within-person variance, but only 0.93% of the between-person variance. In global cognition, the final model (Model 6.5) explained 23.60% of the within-person variance and <0.01% of the between-person variance.

Age and cognition

In all three cognitive domains, as well as the global cognition composite score, a negative association was observed between age at baseline and cognitive performance, indicating that as people aged, their performance on cognitive domains declined.

Table 4. *Multilevel models for memory*

	Model 4.1 N=4941	**Model 4.2** N=4941	**Model 4.3** N= 4806	**Model 4.4** N=4806	**Model 4.5**
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Age at baseline	-.15** (-.16 - -.14)	-.15** (-.16 - -.14)	-.14** (-.15 - -.13)	-.14** (-.15 - -.13)	-.14** (-.15 - -.13)
Alcohol consumption (Ref: Light drinker)					
Non-drinker		-.57** (-.72 - -.42)	-.41** (-.56 - -.26)	-.40** (-.55 -.25)	-.39** (-.54 - -.24)
Moderate		.23** (.09 - .36)	.13 (-.01 - .27)	.12 (-.01 - .26)	.10 (-.03 - .24)
Heavy		.47** (.33 - .60)	.38** (.24 - .51)	.36** (.22 - .50)	.34** (.20 - .48)
Sociodemographic variables					
Gender (Ref: Male)					
Female			.93** (.78 - 1.07)	.93** (.78 - 1.07)	.95** (.80 - 1.10)
Marital status (Ref: Married)					
Single			-.27 (-.57 - .03)	-.27 (-.57 – .03)	-.29 (-.60 - .01)
Divorced/ separated			-.08 (-.30 - .13)	-.09 (-.31 - .12)	-.08 (-.29 - .14)
Widowed			-.05 (-.26 - .17)	-.04 (-.26 - .17)	-.02 (-.24- .20)

*p≤.05; **p≤.01

Table 4. *Multilevel models for Memory (continued)*

	Model 4.1 N=4941 β (95% CI)	**Model 4.2** N=4941 β (95% CI)	**Model 4.3** N=4806 β (95% CI)	**Model 4.4** N=4806 β (95% CI)	**Model 4.5** N=4806 β (95% CI)
Employment status (Ref: In employment)					
Economically inactive			-.36* (-.66 - -.06)	-.30* (-.60 - .01)	-.25 (-.55 - .05)
Carer role			.11 (-.15 - .37)	.11 (-.15 - .37)	.13 (-.13 - .39)
Retired			28* (0.09 - .47)	.27* (.08 - .47)	.29* (.10 - .48)
Childhood SES (Ref: Low)					
Intermediate			.22* (.05 - .38)	.22* (.05 - .38)	.23* (.06 - .39)
High			.30** (.13 - .47)	.30** (.13 - .47)	.31** (.14 - .48)
Education (Ref.: No qualifications)					
High school qualifications			1.15** (.98 - 1.30)	1.13** (.98 - 1.29)	1.12** (.96 - 1.28)
Degree or higher			2.03** (1.80 - 2.26)	2.00** (1.77 - 2.24)	2.00** (1.77 - 2.23)
Current SES (Ref: 1st Quintile)					
2nd Quintile			.37** (.15 - .58)	.35** (.14 - .57)	.33* (.12 - .55)
3rd Quintile			.38** (.16 - .60)	.35* (.13 - .57)	.34* (.11 - .56)
4th Quintile			.74** (.51 - .97)	.71** (.48 - .94)	.68** (.45 - .91)
5th Quintile			.81** (.57 - 1.04)	.76** (.53 - 1.00)	.79** (.73 - .97)

Table 4. *Multilevel model for memory (continued)*

	Model 4.1 N=4941	**Model 4.2** N=4941	**Model 4.3** N=4806	**Model 4.4** N=4806	**Model 4.5** N=4806
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Health behaviours					
Smoking status (Ref: Never smoked)					
Ex-smoker				-.03 (-.17 - .11)	-.01 (-.15 - .12)
Current smoker				-.01 (-.20 - .20)	.02 (-.18 - .22)
Physical activity (Ref: inactive)					
Regular moderate exercise				.25** (.15 - .35)	.22** (.12 - .32)
Mental health					
Depression (Ref. Not depressed)					
Depression (>4 on CES-D)					-.42** (-.56 - -.28)
Model fit					
Within-person variance	4.68 (4.43 - 4.94)	4.53 (4.29 - 4.80)	3.62 (3.40 - 3.85)	3.60 (3.38 - 3.83)	3.58 (3.36 - 3.81)
Between-person variance	5.22 (5.08 - 5.37)	5.22 (5.07 - 5.37)	5.21 (5.06 - 5.36)	5.20 (5.06 - 5.36)	5.17 (5.02 - 5.32)
(*2) Log likelihood		1148.40**	2707.05**	24.30**	668.57**
Intraclass correlation	.47 (.45 - .49)	.46 (.45 - .48)	.41 (.39 - .43)	.41 (.39 - .43)	.41 (.39 - .43)

Model 1 included age at baseline only (n=4941).
Model 2 included age at baseline and alcohol consumption (n=4941).
Model 3 included age at baseline, alcohol consumption and sociodemographic variables (n=4806).
Model 4 included age at baseline, alcohol consumption, sociodemographic variables and health behaviours (n=4806).
Model 5 - the fully adjusted model included age at baseline, alcohol consumption, sociodemographic variables and health behaviours and mental health (n=4806)
*p≤.05; **p≤.01

Alcohol and cognition

In the memory domain with the addition of alcohol to the model, all three drinker groups had significant changes in memory performance across the three waves (Model 4.2). Non-drinkers had a negative association, indicating their performance on memory tasks worsened with time, when compared to the reference group (light drinkers). Both moderate and heavy drinkers showed positive associations, suggesting that as time passed, memory ability for both of these groups did not decline to the same extent as light drinkers. Following adjustment for sociodemographic factors (Model 4.3), moderate drinkers no longer demonstrated a significant association. In the fully adjusted model (Model 4.5), accounting for health behaviours and depression, heavy drinkers continued to demonstrate significantly better memory with time, and non-drinkers persisted to indicate a decline.

Similarly, in verbal fluency, in the unadjusted model (Model 5.2), non-drinkers' performance declined with time, whereas moderate and heavy drinkers showed significant improvement, in relation to light drinkers. In adjusting for the sociodemographic factors (Model 5.3), moderate drinkers once again lost significance. Further adjustment for health variables resulted in heavy drinkers no longer maintaining a significant difference from light drinkers (Model 5.4). In the final model (Model 5.5), non-drinkers maintained a significant negative association, demonstrating a decline in verbal fluency ability with time.

Table 5. *Multilevel models for verbal fluency*

	Model 5.1 N=4941 β (95% CI)	**Model 5.2** N=4941 β (95% CI)	**Model 5.3** N=4806 β (95% CI)	**Model 5.4** N=4806 β (95% CI)	**Model .5** N=4806 β (95% CI)
Age at baseline	-.23** (-.25 - -.21)	-.22** (-.24 - -.20)	-.21** (-.23 - -.18)	-.21** (-.23 - -.18)	-.20** (-.23 - -.18)
Alcohol consumption (Ref: Light drinker)					
Non-drinker		-.81** (-1.09 - -.53)	-.59** (-.87 - -.30)	-.56** (-.85 - -.28)	-.57** (-.86 - -.29)
Moderate		.54** (.28 - .80)	.26 (-.01 - .52)	.23 (-.03 - .49)	.22 (-.04 - .48)
Heavy		.75** (.49 - 1.01)	.30* (.03 - .57)	.26 (-.01 - .53)	.25 (-.01 - .52)
Sociodemographic variables					
Gender (Ref: Male)					
Female			-.01 (-.31 - .28)	.02 (-.28 - .32)	.05 (-.25 - .35)
Marital status (Ref: Married)					
Single			-.68* (-1.30 - -.05)	-.66* (-1.28 - .04)	-.70* (-1.32 - -.10)
Divorced & separated			-.12 (-.56 - .33)	-.10 (-.54 - .34)	-.12 (-.55 - .34)
Widowed			-.02 (-.47 - .43)	.01 (-.44 - .45)	-.01 (-.45 - .46)

*p≤.05; **p≤.01

Table 5. *Multilevel models for verbal fluency (continued)*

	Model 5.1 N=4941 β (95% CI)	**Model 5.2** N=4941 β (95% CI)	**Model 5.3** N=4941 β (95% CI)	**Model 5.4** N=4941 β (95% CI)	**Model 5.5** N=4941 β (95% CI)
Employment status (Ref: in employment)					
Economically inactive			-.73* (-1.34 - -.11)	-.58 (-1.20 - .03)	-.54 (-1.16 - .08)
Carer role			-.08 (-.61 - .46)	-.06 (-.59 - .47)	-.03 (-.57- .50)
Retired			.38 (-.07 - .78)	.38 (-.02 - .78)	.38 (-.02 - .78)
Childhood SES (Ref: Low)					
Intermediate			.53* (.20 - .88)	.53* (.20 - .87)	.55* (.21 - .89)
High			.84** (.48 - 1.19)	.82** (.47 - 1.17)	.83** (.48 - 1.19)
Education (Ref: No qualifications)					
High school qualifications			1.98** (1.67 - 2.32)	1.96** (1.63 - 2.29)	1.96** (1.64 - 2.29)
Degree or higher			3.72** (3.24 - 4.20)	3.64** (3.17 - 4.13)	3.63** (3.15 - 4.11)
Current SES (Ref 1st Quintile)					
2nd Quintile			.69* (.24 - 1.13)	.62* (.17 - 1.06)	.61* (.17 - 1.05)
3rd Quintile			.89** (.43 - 1.34)	.77** (.32 - 1.23)	.76** (.03 - 1.21)
4th Quintile			1.05** (.57 - 1.52)	.94** (.46 - 1.41)	.91** (.43 - 1.38)
5th Quintile			1.39** (.90 - 1.88)	1.25** (.76 - 1.74)	1.21** (.72 - 1.71)

*p≤.05; **p≤.01

Table 5. *Multilevel models for verbal fluency (continued)*

	Model 5.1 N=4941 β (95% CI)	**Model 5.2** N=4941 β (95% CI)	**Model 5.3** N=4806 β (95% CI)	**Model 5.4** N=4806 β (95% CI)	**Model 5.5** N=4806 β (95% CI)
Health behaviours					
Smoking status (Ref. Never smoked)					
Ex-smoker				.17 (-.11 - .45)	-.17 (-.12 - .45)
Current smoker				-.22 (-.63 - .18)	-.61 (-.58 - .20)
Physical activity (Ref. inactive)					
Regular moderate exercise				.55** (.36 - .74)	.54** (.34 - .73)
Mental health					
Depression (Ref. Not depressed)					
Depressed (>4 on CES-D)					-.24 (-.51 - .04)
Model fit					
Within-person variance	20.21 (19.2 -21.29)	19.56 (18.55 -20.62)	16.92 (16.00 – 17.89)	16.77 (15.86 – 17.73)	16.75 (15.84 – 17.71)
Between person variance	17.94 (17.44 – 18.45)	17.94 (17.44 -18.46)	17.89 (17.39 – 18.42)	17.89 (17.38 – 18.41)	17.82 (17.31 – 18.35)
(2*-Log likelihood)		1404.95**	2995.57**	36.64**	756.60**
Intraclass correlation	.53 (.51 -.54)	.52 (.50 - .54)	.48 (.47 - .50)	.48 (.47 - .50)	.48 (.47 -.50)

Model 1 included age at baseline only (n=4941).
Model 2 included age at baseline and alcohol consumption (n=4941).
Model 3 included age at baseline, alcohol consumption and sociodemographic variables (n=4806).
Model 4 included age at baseline, alcohol consumption, sociodemographic variables and health behaviours (n=4806).
Model 5, the fully adjusted model included age at baseline, alcohol consumption, sociodemographic variables and health behaviours and mental health (n=4806)
*p≤.05; **p≤.01

In processing speed, only non-drinkers demonstrated a significant difference from the reference group. This negative association indicated a decline in processing speed across the waves, which persisted into the fully adjusted model (Model 6.5). Heavy drinkers showed a small negative association with processing speed, indicating diminished performance over the course of the study, although this was not significant (β=-0.01 [95% CI: -.25 - .23] p=ns).

Changes in global cognition related to alcohol consumption demonstrated a similar pattern to the memory domain. Non-drinkers experienced a decline with time, whereas heavy drinkers demonstrated less decline in global cognitive ability compared to the light drinker group over the three waves of the study (Model 7.5).

Sociodemographic factors

Some trends were observed for sociodemographic factors added to the cognitive domain models. Higher education, higher childhood and high current SES had positive associations in all cognitive domains, suggesting participants in these groups demonstrated reduced cognitive decline over time.

Table 6. *Multilevel models for processing speed*

	Model 6.1 N=4941	**Model 6.2** N=4941	**Model 6.3** N=4806	**Model 6.4** N=4806	**Model 6.5** N=4806
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Age at baseline	-.16** (-.18 - -.15)	-.16** (-.17 - -.14)	-.15** (-.17 - -.13)	-.15** (-.17 - -.13)	-.15** (-.17 - -.13)
Alcohol consumption (Ref. Light drinker)					
Non-drinker		-.92** (-1.18 - -.66)	-.80** (-1.06 - -.54)	-.78** (-1.05 - -.52)	-.77** (-1.03 - -.51)
Moderate		.23 (-.001 - .46)	.20 (-.03 - .43)	.19 (-.04 - .42)	.18 (-.05 - .42)
Heavy		-.02 (-.25 - .21)	.03 (-.20 - .27)	.01 (-.22 - .25)	-.01 (-.25 - .23)
Sociodemographic variables					
Gender (Ref. Male)					
Female			1.94** (1.68 - 2.20)	1.95** (1.68 - 2.21)	1.96** (1.69 - 2.22)
Marital status (Ref. Married)					
Single			-.49 (-1.04 - .06)	-.49 (-1.04 - .06)	-.53 (-1.08 - .02)
Divorced & separated			.01 (-.34 - .48)	.01 (-.38 - .40)	.03 (-.36 - .42)
Widowed			.29 (-.10 - .69)	.29 (-.10 - .69)	.32 (-.07 - .72)

*p≤.05; **p≤.01

Table 6. *Multilevel models for processing speed (continued)*

	Model 6.1 N=4941 β (95% CI)	**Model 6.2** N=4941 β (95% CI)	**Model 6.3** N=4806 β (95% CI)	**Model 6.4** N=4806 β (95% CI)	**Model 6.5** N=4806 β (95% CI)
Employment status (Ref: in employment)					
Economically inactive			-.80* (-1.34 - -.25)	-.73* (-1.28 - -.19)	-.66* (-1.21 - -.11)
Carer role			.22 (-.24 - .70)	.22 (-.24 - .70)	.23 (-.24 - .70)
Retired			.03 (-.31 - .39)	.03 (-.32 - .38)	.04 (-.31 - .40)
Childhood SES (Ref: Low)					
Intermediate			.21 (-.08 - .51)	.21 (-08 - .51)	.22 (-.09 - .51)
High			.54** (.23 - .85)	.54**(.23 - .85)	.53** (.22 - .84)
Education (Ref: No qualifications)					
High school qualifications			.99** (.71 - 1.28)	.98** (.69 - 1.27)	.97** (.68 - 1.26)
Degree or higher			1.95** (1.53 - 2.38)	1.93** (1.50 - 2.35)	1.90** (1.48 - 2.33)
Current SES (Ref: 1st Quintile)					
2nd Quintile			-.01 (-.39 - .38)	-.02 (-.41 - .37)	-.03 (-.43 - .36)
3rd Quintile			.44* (.04 - .84)	.41* (.01 - .81)	.38 (-.02 - .79)
4th Quintile			.43* (.01 - .84)	.39 (-.02 - .81)	.35 (-.06 - .77)
5th Quintile			.71** (.28 - 1.14)	.66* (.23 - 1.10)	.62* (.19 - 1.05)

*p≤.05; **p≤.01

Table 6. *Multilevel models for processing speed (continued)*

	Model 6.1 N=4941 β (95% CI)	**Model 6.2** N=4941 β (95% CI)	**Model 6.3** N=4806 β (95% CI)	**Model 6.4** N=4806 β (95% CI)	**Model 6.5** N=4806 β (95% CI)
Health behaviours					
Smoking status (Ref: Never smoked)					
Ex-smoker				.03 (-.28 - .22)	-.03 (-.29 - .22)
Current smoker				-.01 (-.36 - .35)	-.01 (-.36 - .36)
Physical activity (Ref: inactive)					
Regular moderate exercise				.27* (.10 - .44)	.25* (.07 - .42)
Mental health					
Depression (Ref:Not depressed)					
Depression (>4 on CES-D)					-.32* (-.57 - -.07)
Model fit					
Within-person variance	14.48 (13.72 -15.28)	14.33 (13.56 -15.13)	12.66 (11.96 - 13.41)	12.65 (11.94 -13.39)	12.62 (11.91 - 13.37)
Between person variance	13.99 (13.58 - 14.40)	14.04 (13.63 - 14.45)	13.91 (13.50 – 14.33)	13.90 (13.49 -14.32)	13.86 (13.45 - 14.28)
Log likelihood		1184.77**	2744.77**	9.48*	686.56**
Intraclass correlation	.51 (.49 - .52)	.50 (.49 - .52)	.48 (.46 - .49)	.48 (.46 - .49)	.48 (.46 - .49)

Model 1 included age at baseline only (n=4941).
Model 2 included age at baseline and alcohol consumption (n=4941).
Model 3 included age at baseline, alcohol consumption and sociodemographic variables (n=4806).
Model 4 included age at baseline, alcohol consumption, sociodemographic variables and health behaviours (n=4806).
Model 5, the fully adjusted model included age at baseline, alcohol consumption, sociodemographic variables and health behaviours and mental health (n=4806).
*p≤.05; **p≤.01

Health behaviours

For health behaviours, smoking status failed to generate a significant contribution to change over time on any of the cognitive domains. Conversely, regular physical activity was positively associated with all cognitive domains, indicating that participants who engaged in regular moderate exercise experienced less cognitive decline than those who did not.

Depression

A negative association was observed for depression (>4 on CES-D) in memory, processing speed and global cognition. This suggests depressed participants experienced greater decline in their ability on these domains when compared to participants who did not meet the criteria for depression (<4 on CES-D). No significant association was observed for depression in verbal fluency over time.

Table 7. *Multilevel models for global cognition*

	Model 7.1 N=4806 β (95% CI)	**Model 7.2** N=4806 β (95% CI)	**Model 7.3** N=4806 β (95% CI)	**Model 7.4** N=4806 β (95% CI)	**Model 7.5** N=4806 β (95% CI)
Age at baseline	-.11** (-.11 - -.10)	-.10** (-.11 - -.10)	-.10** (-.11 - -.09)	-.10** (-.11 - -.09)	-.10** (-.11 - -.09)
Alcohol consumption (Ref: Light drinker)					
Non-drinker		-.60** (-.34 - -.17)	-.20** (-.28 - -.11)	-19** (-.28 - -.11)	-.20** (-.28 - -.11)
Moderate		.13** (.05 - .20)	.07 (.01 - .15)	.07 (-.01 - .14)	.06 (-.01 - .14)
Heavy		.17** (.10 - .25)	.10* (.02 - .18)	.09* (.01 - .17)	.08* (-.01 - .16)
Sociodemographic variables					
Gender (Ref: Male)					
Female			.61** (.51 - .71)	.62** (.52 - .72)	.62** (.52 - .72)
Marital status (Ref: Married)					
Single			-.25* (-.46 - -.042)	-.25* (.45 - -.04)	-.26* (.46 - -.05)
Divorced & separated			.01 (-.14 - .15)	.01 (-.14 - .15)	.01 (-.13 - .16)
Widowed			.05 (-.10 - .20)	.05 (-.10 - .20)	.06 (-.09 - .21)
Employment status (Ref: in employment)					
Economically inactive			-.35** (-.56 -.15)	-.32* (-.53 - -.12)	-.29* (-.50 - -.09)
Carer role			.08 (-.09 - .26)	.01 (-.09 - .27)	.10 (-.08 - .28)
Retired			.14 (.01 - .27)	.14* (.01 - .27)	.14* (.01 - .28)

*p≤.05; **p≤.01

Table 7. *Multilevel models for global cognition (continued)*

	Model 7.1 N=4981 β (95% CI)	**Model 7.2** N=4981 β (95% CI)	**Model 7.3** N=4806 β (95% CI)	**Model 7.4** N=4806 β (95% CI)	**Model 7.5** N=4806 β (95% CI)
Childhood SES (Ref: Low)					
Intermediate			.19** (.08 - .30)	.19** (.08 - .30)	.20* (.08 - .03)
High			.31** (.20 - .44)	.31** (.20 - .43)	.32** (.20 - .43)
Education (Ref: No qualifications)					
High school qualifications			.83** (.72 - .93)	.82** (.71 - .93)	.82** (.71- .93)
Degree or higher			1.55** (1.39 – 1.71)	1.53** (1.37 – 1.69)	1.53** (1.37 - 1.69)
Current SES (Ref: 1st Quintile)					
2nd Quintile			.25** (.10 - .40)	.23* (.08 - .38)	.23* (.08 - .34)
3rd Quintile			.36** (.21 - .52)	.34** (.18 - .49)	.33** (.18 - .49)
4th Quintile			.50** (.35 - .66)	.48** (.32 - .63)	.46** (.30 - .62)
5th Quintile			.64** (.48 - .80)	.61 ** (.44 - .77)	.59** (.43 - .75)

*p≤.05; **p≤.01

Table 7. *Multilevel model for global cognition (continued)*

	Model 7.1 N=4941 β (95% CI)	**Model 7.2** N=4941 β (95% CI)	**Model 7.3** N=4806 β (95% CI)	**Model 7.4** N=4806 β (95% CI)	**Model 7.5** N=4806 β (95% CI)
Health behaviours					
Smoking status (Ref: Never smoked)					
Ex-smoker				.04 (-.46 - .14)	.05 (-.05 - .14)
Current smoker				-.06 (-.19 - .06)	-.06 (-.19 - .06)
Physical activity (Ref: inactive)					
Regular moderate exercise				.12** (.06 - .17)	.11** (.05 - .17)
Mental health					
Depression (Ref: Not depressed)					
Depression (>4 on CES-D)					-.15** (-.22 - -.07)
Model fit					
Within-person variance	2.67 (2.55 - 2.79)	2.60 (2.48 – 2.73)	2.07 (1.98 – 2.12)	2.06 (1.96 – 2.16)	2.04 (1.94 – 2.14)
Between person variance	1.29 (1.26 – 1.33)	1.30 (1.26- 1.34)	1.29 (1.26 – 1.33)	1.29 (1.25 – 1.33)	1.29 (1.25 – 1.33)
(2*-Log likelihood)		770.45**	2394.84**	21.32**	410.62**
Intraclass correlation	.67 (.66 -.68)	.68 (.65 - .68)	.61 (.61 – .61)	.61 (.60 - .63)	.61 (.60 - .63)

Model 1 included age at baseline only (n=4941).
Model 2 included age at baseline and alcohol consumption (n=4941).
Model 3 included age at baseline, alcohol consumption and sociodemographic variables (n=4806).
Model 4 included age at baseline, alcohol consumption, sociodemographic variables and health behaviours (n=4806).
Model 5- the fully adjusted model included age at baseline, alcohol consumption, sociodemographic variables and health behaviours and mental health (n=4806)
*p≤.05; **p≤.01

Discussion

This study aimed to examine the relationship between alcohol consumption and cognitive function in older adults as they aged. Older adults' cognitive performance in memory, verbal fluency, processing speed, and global cognition declined over the three waves included in the study. In relation to alcohol consumption, non-drinkers demonstrated significantly greater decline on all cognitive domains. Conversely, heavy drinkers (consuming >14 units/week) demonstrated the least decline on memory and global cognition. For health behaviours, smoking status had no significant association with older adult's cognitive decline, but physical activity was consistently positively associated with a reduced decline in cognitive performance as people aged. Depression was negatively associated with the change in memory, processing speed, and global cognition performance across the study, but demonstrated no significant association with verbal fluency. Additionally, trends were observed for sociodemographic factors which persisted in the fully adjusted models; for example, higher education, higher childhood SES, and higher current SES contributed to reduced cognitive decline with time in all cognitive domains.

The increased cognitive decline of non-drinkers is in line with many previous studies in this area. However, the findings relating to heavy alcohol consumption indicating lesser decline in memory and global cognition, is in contrast to much of the previous literature (Downer et al., 2015; Reid et al., 2006). The present findings are in conflict with the U-shaped curve which describes non-drinkers and heavy drinkers as having similar, poor performance on cognitive tasks. Non-drinkers' decline in memory performance over time has been reported by a number of studies (Elias et al., 1999; Herring and Paulson, 2018; Lambert, 2016). However, research with heavy older drinkers typically report impairments in memory, contrary to the present findings (Ros-Cucurull et al., 2018; Sabia et al., 2014). The categorisation of

'heavy' drinkers in alcohol research varies greatly between studies, so direct comparison is done with caution. Sabia et al. (2014) reported a decline in memory over time for heavy drinkers, consuming ≥3.6 units of alcohol on average, per day. This could be considerably more alcohol than was observed in the heavy drinker group of the present study. Other authors have categorised anything greater than 7 units per week as 'heavy' or 'at-risk' drinking, although both studies reported no significant difference between the non-drinker and drinker groups on memory tasks (Wardazala et al., 2018; Zanjani et al., 2013).

There is extensive research in the working age adult population (i.e. <65years) linking chronic heavy alcohol consumption to executive function deficits, and reduced ability to appropriately self-monitor (Brion et al., 2018; Verdejo-Garcia, Lawrence and Clark, 2008; Woods et al., 2016). Previous studies have utilised a verbal fluency task comparable to the present study and reported a similar increased decline over time for non-drinkers (Herring and Paulson, 2018; Kesse-Guyout et al., 2012). Fluency tasks require the individual to self-monitor as they generate an appropriate response while inhibiting any erroneous responses that come to mind. A number of older adult studies have observed a decline in fluency performance for heavier drinkers (Gross et al., 2011; Sabia et al., 2014). However, inconsistencies exist, as Downer et al., (2015), categorised heavy drinking as >15 units/week), and failed to report a significant adverse effect of alcohol consumption in executive function. Other studies have incorporated additional executive function assessments, such as Trail Making Tests (Reitan, 1971), but reported similar findings in relation to non-drinkers, indicating a greater risk of decline over time (Ganguli et al., 2005).

Processing speed is an area of cognition that sees an accelerated decline from age 60 onwards (Salthouse, 2009), and an increased decline was observed in the present study as people aged. Non-drinkers had the greatest decline with time, but no level of alcohol consumption was related to processing speed over the course of the study. Processing speed

and alcohol consumption has produced inconsistent results in other longitudinal studies, which frequently report non-significant findings with increased alcohol consumption (Corley et al., 2011; Hogenkamp et al., 2014; Zanjani et al., 2013). However, alcohol consumption has been associated with reduced risk of decline for alcohol drinkers (categorised as people who consume any amount of alcohol) in processing speed compared to non-drinkers (Nurk et al., 2007), similar to the current findings.

The results in the individual domains provide greater insight into cognitive functioning, but global cognition gives an overview of the participants' performance. Heavy drinkers showed the least decline on global cognition, whereas as non-drinkers had the greatest decline. Few other studies have reported positive association of global cognitive ability with heavy alcohol consumption, whereas non-drinkers, in line with the 'sick quitter' explanation, have frequently been described as showing the greatest decline in global cognitive tasks (Ganguli et al., 2005; Monds et al., 2017; Sabia et al., 2014; Yaffe et al., 2016).

Previous research has suggested that the cardiovascular benefits associated with low levels of alcohol consumption are linked to improved cognition for drinkers. The anti-inflammatory properties of alcohol are linked to improvement in blood pressure, lipid profile, haemostasis, and endothelial function (Katsiki, Tziomalos, and Mikhailidis, 2014). Red wine in particular has been linked to positive cardiovascular function due to its antioxidant polyphenol ingredients (Nurk et al., 2007). This explanation has been popular in both research and mainstream media since it was first proposed in the 1980s. However recent research has discredited this claim. A recent study, examining the supposed protective effects of alcohol in a range of physical illnesses found that even drinking within the national guidelines was causing significant harm (Wood et al., 2018). The only health problem for which there was a reduced risk was myocardial infarction, and this was minimal. The contemporary view is that the physiological damage caused by alcohol far outweighs the reported cardiovascular effects

(Conor, Haber and Hall, 2016), and some researchers in the area of alcohol research have suggested a review of the alcohol guidelines, with a view to reducing the current recommendations (Burton and Sheron, 2018; Griswold et al., 2018).

There may be important characteristic differences between the non-drinker and heavy drinker groups which contribute to their cognitive decline profiles in the present study. Alcohol consumption has been associated with higher education and higher SES in previous research, whereas non-drinking has been linked with less educated and socially deprived groups (Ipparraguire, 2015; Naimi et al., 2013). Education and SES are linked to better cognitive outcomes throughout life (Corley et al., 2011; Ritchie et al., 2016). A lower proportion (<10%) of the non-drinkers attained third level education compared to the heavy drinker group (approximately 30%) in the present sample.

A similar pattern was observed in current SES, as a relatively small proportion of non-drinkers were present in the highest SES quintile, whereas the majority of heavy drinkers were, suggesting greater affluence in the heavy drinking group. Equally, the ability to consume alcohol may be indicative of someone who is physically, mentally, and cognitively fit enough to engage in social activity. Alcohol consumption in the UK is a feature of many social gatherings, and for most people drinking alcohol occurs in the context of social activity (Emslie, Hunt, and Lyons, 2012). Older people who maintain good cognitive ability into old age are more likely to remain involved in social activities, sports, and leisure pursuits whereas people who become aware of a decline in their cognitive ability often withdraw from social encounters (Murphy et al., 2007). Withdrawing may be doubly problematic, as social isolation is linked to depression, which may contribute to reduced cognitive ability (Shankar et al., 2017). In the present study, depression was negatively associated with cognitive ability in memory, processing speed and global cognition. While the number of people categorised as depressed was low (8-25%), a higher proportion of non-drinkers met the criteria for depression

in all waves. Physical activity often incorporates social interaction and has been associated with better cognition in old age (Helmes and Harris, 2017). Regular exercise was consistently associated with less decline in all domains included in the present study, after accounting for the contributions of alcohol, sociodemographic, and mental health factors.

It may be that heavy alcohol consumption in the current sample is indicative of other characteristics associated with better cognition in old age, and the heavy drinkers may represent the most educated, wealthy, and physically able group. Nevertheless, we cannot rule out the 'sick quitter' effect, in that those who are not consuming alcohol are doing so due to other ailments which may in turn be affecting their cognitive performance. Horvat et al., (2014) found that people who had quit drinking accounted for the poor cognitive performance of non-drinkers in their study.

Strengths and limitations

The present study has a number of limitations which should be addressed. First, the reliance on self-report measures to assess alcohol consumption means participants may have unintentionally or intentionally underreported the amount of alcohol consumed (Dufour, 1999). Questions in ELSA relating to alcohol consumption ask about specific alcohol types, and this has been found to reduce the underreporting of alcohol consumption and encourage a more accurate answer (Downer et al., 2015). Second, using alcohol data from Wave 0 and embedding it into Wave 1 to form the baseline meant that information relating to participants' alcohol use was from 2-3 years prior to their first cognitive assessment. It is possible that people's alcohol consumption changed in that time period. However, previous research has reported that a small percentage (6%) of older participants reported changes in alcohol consumption over a five-year period, so it is hoped any change in the present sample was negligible (Ruitenberg et al., 2002). Third, labelling drinking more than 14 units of alcohol a week as 'heavy' may be misleading.

This categorisation is widely used in alcohol research, but only represents people drinking over the recommended guidelines, rather than excessive or problematic alcohol use. While there were people in our sample who drank >28 units weekly, this group was too small for meaningful use in the analyses. Fourth, the lack of additional information relating to people's drinking behaviour, such as fluctuations in levels of consumption or frequency throughout life, the context of alcohol consumption, and reasons for not drinking alcohol is a further limitation. The non-drinker group in this study was comprised of people who had never drank alcohol as well as those who had quit drinking, but there was no way to distinguish between these groups. Fifth, relating to cognition, a limitation of the current study is that there was no available information relating to prior cognitive ability earlier in life, prior to the onset of old age. This is not uncommon in research in this area, but the Lothian Birth Cohort Study 1936 linked older adult's cohort data with their childhood IQ assessments at age 11. They found that older adults' childhood cognitive ability accounted for a large proportion of the variance in older adults' cognitive performance, and this has not been controlled for in the present study (Corley et al., 2011). Finally, in the present study domains of cognition were measured by single assessments, and it is acknowledged that multiple assessments would have provided a more robust representation of the respective domains (Salthouse, 2019).

Despite the number of limitations, this study contributes to the research exploring the association between alcohol consumption in old age with cognitive ability. It is one of the few longitudinal studies assessing alcohol consumption and domain-specific cognitive change in older people. Additionally, this study benefitted from a large sample which is nationally representative of the older English population (Steptoe et al., 2012), and all participants were assessed at three timepoints, spanning eight years. Furthermore, unlike many other studies exploring the association of alcohol consumption and cognition, heavy alcohol drinkers were

well represented in the present sample (approximately 20% at all waves), allowing for fair robust comparisons between the alcohol drinking groups. While there were differences in alcohol data across the waves, cognition was consistently assessed using the same measures across the three waves, providing a robust assessment of within-person cognitive change with time. Additionally, the present study categorised non-drinkers as those who had not consumed alcohol in the past 12 months, unlike many studies which often use the last week, and this created a more accurate representation of non-drinkers.

Longitudinal research is central to understanding the cognitive changes that occur with age and datasets such as ELSA provide a valuable platform for this. This is also true for exploring the long-term effects of alcohol consumption as randomised control trials are not a feasible method of assessment in this area (Peters et al., 2008). In our study we restricted the sample to participants who were present at three waves (1, 4, and 5), and had cognitive data for at least two, in order to observe change with time. Although not an uncommon selection method in longitudinal analyses, other studies may use all available participants and then account for the attrition in sensitivity analyses. The exclusions imposed by the present study may have inadvertently selected the healthiest participants, as other participants experiencing increased cognitive decline may have left the study or passed away. This 'survivor effect' may have contributed to our finding that heavy drinking has a positive association with memory and global cognitive ability, when it may be other factors relating sociodemographic, physical health and activity, which account for this.

Research and clinical implications

The factors that contribute to age-related cognitive change are likely to have complex interactions. As older people have lived whole lives before they engage in later-life research, a

large portion of their life – sociodemographic factors, physical and mental health, is unaccounted for, and future research should consider the best way to capture this. Studies such as this one present a small proportion of the alcohol consuming population and results cannot be generalised to older people who are drinking alcohol at excessive or problematic levels. Established longitudinal cohort studies should consider the inclusion of lifetime alcohol consumption assessment, to capture more detail about alcohol use in older people and how this may have changed throughout their life. This information may highlight important distinctions between the so called 'sick quitters' and ex-drinkers, who are reported to have different characteristics which may impact their cognitive ability (Wannamethee et al., 2002; Reid, 2006).

In relation to the clinical implications, despite the findings of the present study, alcohol misuse in the older adult population remains a current public health concern (Drink Well, Age Well, 2016). Clinicians should continue to assess older peoples' alcohol consumption and provide informed advice on the associated risks. Additionally, clinicians should disseminate research responsibly to the clinical groups they work with. Alcohol use attracts media interest in the UK, and findings such as the those in this study frequently make their way into news and media outlets, heralding the supposed benefits of alcohol consumption. Educating service users about the methodological issues associated with older adult research, such as the 'survivor effect', use of dementia screens with healthy participants, and the underrepresentation of heavy drinkers, will encourage service users' critical evaluation of the articles featuring in the media. Additionally, promoting physical activity and social engagement for older adults could be beneficial in maintaining cognitive ability into old age.

Conclusion

In this longitudinal study, non-drinkers demonstrated the greatest age-related cognitive decline compared to drinker groups. Heavy drinkers demonstrated the least decline in memory, and in global cognition. While these findings suggest a protective effect of alcohol consumption on older adults' cognition, no such recommendations are being made. Alcohol remains a hazardous substance, with more than 2.5 million deaths per year related to alcohol consumption globally (WHO, 2018). In older adults, the consumption of alcohol may be indicative of an active social life and good health, the interplay of which future studies ought to address.

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Appendix A. Guidelines for publication, Ageing and Society

CAMBRIDGE | Instructions for Contributors

Ageing & Society Submission

Ageing and Society is an interdisciplinary and international journal devoted to the understanding of human ageing and the circumstances of older people in their social and cultural contexts. We invite original contributions that fall within this broad remit and which have empirical, theoretical, methodological or policy relevance. All submissions, regardless of category, are subject to blind peer-review. Authors are reminded of the requirement to avoid ageist and other inappropriate language and to avoid the stereotypical representation of individuals or groups.

All papers must be submitted using Manuscript Central through the Journal's website at: http://journals.cambridge.org/aso.

All books for review should be sent to: Caroline Norrie and Kritika Samsi, Social Care Workforce Research Unit, King's College London, Strand, London, WC2R 2LS

All submissions must conform to the submission guidelines outlined below. Failure to do so may result in the submission being rejected.

Article categories

Research articles

Research articles must contain between 3,000 and 9,000 words, excluding the abstract and references. Most papers usually have the following sections in sequence: Title page, Abstract (200-300 words), Keywords (three to eight), Main text, Statement of ethical approval as appropriate, Statement of funding, Declaration of contribution of authors, Statement of conflict of interest, Acknowledgements, Notes, References, Correspondence address for corresponding author. However authors have the flexibility to organise the main text of article into the format that best suits the topic under consideration.

Forum articles

In addition to research papers, the Journal welcomes critical/reflective commentaries on contemporary research, policy, theory or methods relevant to the Journal's readers. These articles reflect a viewpoint of the author and they may form part of an ongoing debate. These articles should contain 2,000-5,000 words. There is no preset organisational structure.

Special issues

Proposals are invited for special issues that fall within the remit of the journal. Ageing & Society especially looks for proposals that show originality and which address topical themes. Proposals which involve authors from a range of disciplines and/or countries are particularly encouraged and the special issue must demonstrate clear added value in advancing an understanding of ageing and later life that is more than the sum of the individual papers.

Proposal should be submitted by the co-ordinating Guest Editors by email to the Editor, Christina Victor: christina.victor@brunel.ac.uk

Proposals are reviewed twice a year, for further information see the guidelines for special issue proposals available at:
http://journals.cambridge.org/images/fileUpload/images/A&S_Special_Issue_Proposals.pdf

It is Ageing & Society practice that all papers in special issues are subject to blind peer review, undergoing the same refereeing process as all other submissions, led by the Ageing & Society Editor and co-ordinated by the journal's Editorial Assistant. The final decision whether to publish individual papers submitted as part of a special issues remains with the Editor.

Submission requirements

Exclusive submission to Ageing & Society

• Submission of the article to Ageing & Society is taken to imply that it has not been published elsewhere nor is it being considered for publication elsewhere. Authors will be required to confirm on submission of their article that the manuscript has been submitted solely to this journal and is not published, in press, or submitted elsewhere. Where the submitted manuscript is based on a working paper (or similar draft document published online), the working paper should be acknowledged and the author should include a statement with the submitted manuscript explaining how it differs from the working paper. Articles which are identical to a working paper or similar draft document published online will not be accepted for publication in Ageing & Society.

Appropriateness for Ageing Society

- All submissions must fall within the remit of the journal, as described at the beginning of this document.
- All manuscripts must meet the submission requirements set out in this document, closely following the instructions in the 'Preparation of manuscripts', 'Citation of references' and 'Table and Figures' sections below.
- Authors are requested to bear in mind the multi-disciplinary and international nature of the readership when writing their contribution. Care must be taken to draw out the implications of the analysis for readers in other fields, other countries, and other disciplines. Papers that report empirical findings must detail the research methodology.
- The stereotypical presentation of individuals or social groupings, including the use of ageist language, must be avoided.

Submission documents

All submissions should include:

- A copy of the complete text of the manuscript, with a title page including the title of the article and

  the author(s)' names, affiliations and postal and email addresses.

- A copy of the complete text minus the title page, acknowledgements, and any running headers of

  author names, to allow blinded review.

Named authors

- Papers with more than one author must designate a corresponding author. The corresponding author should be the person with full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. The corresponding author must confirm that co-authors have read the paper

and are aware of its submission. Full contact details for all co-authors should be submitted via Manuscript Central.

- All named authors for an article must have made a substantial contribution to: (a) the conception and design, or analysis and interpretation of data; (b) the drafting of the article or revising it critically for important intellectual content and (c) approval of the version to be published. All these conditions must all be met. Participation solely in the acquisition of funding or the collection of data does not, of itself, justify authorship.

Peer-review process

- The corresponding author should prepare (a) a complete text and (b) complete text minus the title page, acknowledgements, and any running headers of author names, to allow blinded review. References to previous papers of the authors must not be blinded, neither in the text nor in the list of references.
- Papers are peer-reviewed. Authors may be asked to submit a revised version of the original paper. In any revised submission, we prefer you to indicate these revisions using track changes where appropriate. An accompanying letter from the corresponding author should outline your changes, and comments on advice that you have chosen not to accept. The corresponding author should confirm that co-authors have agreed to any changes made.

Ethical considerations

• Where the paper reports original research, confirmation must be given that ethical guidelines have been met, including adherence to the legal requirements of the study country. For empirical work conducted with human subjects authors must provide evidence that the study was subject to the appropriate level of ethical review (e.g. university, hospital etc.) or provide a statement indicating that it was not required. Authors must state the full name of the body providing the favourable ethical review and reference number as appropriate.

Declaration of funding

• A declaration of sources of funding must be provided if appropriate. Authors must state the full official name of the funding body and grant numbers specified. Authors must specify what role, if any, their financial sponsors played in the design, execution, analysis and interpretation of data, or writing of the study. If they played no role this should be stated.

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Preparation of manuscripts

All contributions (articles, reviews and all types of review articles) should be typed double-spaced with at least one-inch or two-centimetre margins throughout (including notes and the list of references).

Most research articles usually have the following sections in sequence: Title page, Abstract (200-300 words), Keywords (three to eight), Main text, Statement of ethical approval as appropriate, Statement of funding, Declaration of contribution of authors, Statement of conflict of interest, Acknowledgements, Notes, References, Correspondence address for corresponding author.

The title page should give the title of the article and the author(s)' names, affiliations and postal and email addresses. When composing the title of your article, please give consideration to how the title would be shortened to appear as a running head in final version of the Journal.

The tables and figures should be presented one to a page in sequence at the end of the paper. Black and white photographs may be submitted where they are integral to the content of the paper. Charges apply for all colour figures that appear in the print version of the Journal (see below for further details).

Authors are asked to follow the current style conventions as closely as possible. Please consult a very recent issue of the journal. In particular, please note the following:

- Use the British variants of English-language spelling, so 'ageing', not 'aging'.
- **First level headers are in bold, sentence case and left justified**
- *Second level headers are in italic (not bold), sentence case and left justified*
- Do not number paragraphs or sections. Avoid very short (particularly one sentence) paragraphs.
- Do not use **bold text** in the text at all. For emphasis, use italic.
- In the main text, the numbers one to ten should be written as words, but for higher numbers the numerals (e.g. 11, 23, 364) should be used.
- All acronyms must be expanded on first use, even EU, USA, UK or UN, for those which are commonplace in one country are not in others.
- Do not use footnotes. Endnotes are permitted for technical and information details (including arrays of test statistics) that distract from the main argument. Endnote superscripts should be placed outside, not inside a punctuation mark (so.[3] not[4].).
- Write per cent (not %) except in illustrative brackets.

Authors, particularly those whose first language is not English, may wish to have their English-language manuscripts checked by a native speaker before submission. This is optional, but may help to ensure that the academic content of the paper is fully understood by the editor and any reviewers. We list a number of third-party services specialising in language editing and/or translation, and suggest that authors contact as appropriate:
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Please note that the use of any of these services is voluntary, and at the author's own expense. Use of these services does not guarantee that the manuscript will be accepted for publication, nor does it restrict the author to submitting to a Cambridge published journal.

Citation of references

Contributors must follow the standard conventions for the in-text citation of sources (author/date system).

Contributors must give the author's surname, date of publication and page references (if any) in parentheses in the body of the text, e.g. (Cole 1992: 251). For references with one to three authors, all authors should be named (Black, Green and Brown 2003). For references with four or more authors, the following form is required: (Brown *et al.* 2003). Note that all authors must be named in the list of references, and *et al.* is not permitted in the list. A complete list of references cited, arranged alphabetically by authors' surname, should be typed double-spaced at the end of the article in the form:

Balsa AI, Homer JF, Fleming MF and French MT (2008) Alcohol consumption and health among elders. The Gerontologist 48, 5, 622–636.

Bergmann MM, Rehm J, Klipstein-Grobusch K, Boeing H, Schütze M, Drogan D, Overvad K, Tjønneland A, Halkjær J, Fagherazzi G, Boutron-Ruault M-C, Clavel-Chapelon F, Teucher B, Kaaks R, Trichopoulou A, Benetou V, Trichopoulos D, Palli D, Pala V, Tumino R, Vineis P, Beulens JWJ, Redondo M-L, Duell EJ, Molina-Montes E, Navarro C, Barricarte A, Arriola L,
Allen NE, Crowe FL, Tee Khaw K, Wareham N, Romaguera D, Wark PA, Romieu I, Nunes L, Riboli E and Ferrari P (2013) The association of pattern of lifetime alcohol use and cause of death in the European

prospective investigation into cancer and nutrition (EPIC) study. International Journal of Epidemiology 42, 6, 1772–1790.

Citation of Internet pages or publications that are available online

Give authors, date, title, publisher (or name of host website) as for a printed publication. Then follow with ... Available online at ... full Internet address [Accessed date]. For example:

Belfield C, Cribb J, Hood A and Joyce R (2014) *Living Standards, Poverty and Inequality in the UK: 2014.* Institute for Fiscal Studies, London. Available online at http://www.ifs.org.uk/publications/7274 [Accessed 30 July 2015].

Tables and figures

There should never be more than ten tables and figures in aggregate, and only in exceptional circumstances more than eight. Please do not use Boxes or Appendices. Present all illustrative material as tables or figures. Please indicate in the text where approximately the Table and Figures should appear using the device < Insert Table 1 about here > on its own line. For figures generated by Excel, please send the original file (rather than a 'picture' version) so that the figures can be copy-edited.

Tables and figures should be clearly laid out on separate pages, numbered consecutively, and designed to fit a printed page of 228 x 152 mm (actual text area 184 x 114 mm). Titles should be typed above the body of the table, with an initial capital only for the first word and proper names and italicised or underlined (for italics). Vertical lines should not be used and horizontal lines should be used only at the top and bottom of the table and below column headings. Authors are asked to give particular attention to the title and to column and row labels (they are often poorly selected, incomprehensible or inadequate). All multiple word labels should be in sentence case. Short titles that concentrate on the subject of the table are recommended. Technical or methodological details (such as sample size or type of statistic) should be described in the labels or in table notes. Spurious accuracy should be avoided: most statistics justify or require only one decimal place.

Figures should also be provided on separate pages and numbered consecutively. For each figure, the caption should be below and in sentence case. Separate lists of captions are not required.

Colour figures can be submitted to Ageing & Society, but charges apply for all colour figures that appear in the print version of the journal. At the time of submission, contributors should clearly state whether their figures should appear in colour in the online version only, or whether they should appear in colour online *and* in the print version. There is no charge for including colour figures in the online version of the Journal but it must be clear that colour is needed to enhance the meaning of the figure, rather than simply being for aesthetic purposes. If you request colour figures in the printed version, you will be contacted by CCC- Rightslink who are acting on our behalf to collect Author Charges. Please follow their instructions in order to avoid any delay in the publication of your article.

Figures should be provided in the following formats:
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Proofs will be sent to the corresponding author as a PDF via email for final proof reading. The proofs should be checked and any corrections returned within 2 days of receipt. The publisher reserves the right to charge authors for excessive correction of non-typographical errors.

Authors will receive a PDF of the published paper and a copy of the Journal, to go to the corresponding author.

Last updated 6th June 2019

Appendix B. The Quality Assessment Tool for Quantitative Studies (QATQS)

QUALITY ASSESSMENT TOOL FOR QUANTITATIVE STUDIES

EPHPP
Effective Public Health Practice Project

COMPONENT RATINGS

A) SELECTION BIAS

(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?

1 Very likely
2 Somewhat likely
3 Not likely
4 Can't tell

(Q2) What percentage of selected individuals agreed to participate?

1 80 - 100% agreement
2 60 – 79% agreement
3 less than 60% agreement
4 Not applicable
5 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

B) STUDY DESIGN

Indicate the study design

1 Randomized controlled trial
2 Controlled clinical trial
3 Cohort analytic (two group pre + post)
4 Case-control
5 Cohort (one group pre + post (before and after))
6 Interrupted time series
7 Other specify _____
8 Can't tell

Was the study described as randomized? If NO, go to Component C.

No Yes

If Yes, was the method of randomization described? (See dictionary)

No Yes

If Yes, was the method appropriate? (See dictionary)

No Yes

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

C) CONFOUNDERS

(Q1) Were there important differences between groups prior to the intervention?

1 Yes
2 No
3 Can't tell

The following are examples of confounders:

1 Race
2 Sex
3 Marital status/family
4 Age
5 SES (income or class)
6 Education
7 Health status
8 Pre-intervention score on outcome measure

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?

1 80 – 100% (most)
2 60 – 79% (some)
3 Less than 60% (few or none)
4 Can't Tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

D) BLINDING

(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?

1 Yes
2 No
3 Can't tell

(Q2) Were the study participants aware of the research question?

1 Yes
2 No
3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

E) DATA COLLECTION METHODS

(Q1) Were data collection tools shown to be valid?

1 Yes
2 No
3 Can't tell

(Q2) Were data collection tools shown to be reliable?

1 Yes
2 No
3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

Appendix B. The Quality Assessment Tool for Quantitative Studies (QATQS)

F) WITHDRAWALS AND DROP-OUTS

(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?

1 Yes
2 No
3 Can't tell
4 Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).

1 80 -100%
2 60 - 79%
3 less than 60%
4 Can't tell
5 Not Applicable (i.e. Retrospective case-control)

RATE THIS SECTION	STRONG	MODERATE	WEAK	
See dictionary	1	2	3	Not Applicable

G) INTERVENTION INTEGRITY

(Q1) What percentage of participants received the allocated intervention or exposure of interest?

1 80 -100%
2 60 - 79%
3 less than 60%
4 Can't tell

(Q2) Was the consistency of the intervention measured?

1 Yes
2 No
3 Can't tell

(Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?

4 Yes
5 No
6 Can't tell

H) ANALYSES

(Q1) Indicate the unit of allocation (circle one)

community organization/institution practice/office individual

(Q2) Indicate the unit of analysis (circle one)

community organization/institution practice/office individual

(Q3) Are the statistical methods appropriate for the study design?

1 Yes
2 No
3 Can't tell

(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?

1 Yes
2 No
3 Can't tell

GLOBAL RATING

COMPONENT RATINGS

Please transcribe the information from the gray boxes on pages 1-4 onto this page. See dictionary on how to rate this section.

A	**SELECTION BIAS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
B	**STUDY DESIGN**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
C	**CONFOUNDERS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
D	**BLINDING**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
E	**DATA COLLECTION METHOD**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	
F	**WITHDRAWALS AND DROPOUTS**	**STRONG**	**MODERATE**	**WEAK**	
		1	2	3	Not Applicable

GLOBAL RATING FOR THIS PAPER (circle one):

1 STRONG (no WEAK ratings)
2 MODERATE (one WEAK rating)
3 WEAK (two or more WEAK ratings)

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-F) ratings?

No Yes

If yes, indicate the reason for the discrepancy

1 Oversight
2 Differences in interpretation of criteria
3 Differences in interpretation of study

Final decision of both reviewers (circle one):

1 STRONG
2 MODERATE
3 WEAK

Appendix C. Quality assessment of included studies using the *Quality Assessment Tool For Quantitative Studies (QATQS).*

First author Year	*Selection Bias*	*Study Design*	*Confounders*	*Blinding*	*Data Collection Method*	*Withdrawals & Dropouts*	*Intervention Integrity*	*Analyses*	*Global Rating*
Beydoun 2014	3	2	3	-	2	3	1	1	Weak
Bond 2001	2	2	2	-	2	2	1	1	Moderate
Corley 2011	2	2	1	-	2	1	1	1	Moderate
Downer 2015	2	2	1	-	1	-	1	1	Strong
Espeland 2006	2	2	1	-	3	1	1	1	Moderate
Fischer 2018	3	2	1	-	1	2	1	3	Moderate
Ganguli 2005	3	2	2	-	1	1	1	2	Weak
Hassing 2018	2	2	1	-	2	1	1	2	Moderate
Hebert 1993	2	2	2	-	1	1	1	1	Moderate
Herring 2018	2	2	2	-	2	2	1	1	Moderate
Hogenkamp 2014	1	2	1	-	1	1	1	1	Strong
Kalapatapu 2017	2	2	1	-	1	-	1	1	Strong
McDougall 2006	3	2	1	-	3	-	2	3	Weak
Moussa 2015	2	2	2	-	1	-	1	1	Moderate
Ngandu 2007	2	2	2	-	1	3	3	3	Weak
Nurk 2008	2	2	1	-	1	1	1	1	Strong

Appendix C. Quality assessment of included studies using the *Quality Assessment Tool For Quantitative Studies (QATQS). (Cont'd.)*

Reid 2006	2	2	1	-	1	-	1	1	Strong
Wardazala 2018	2	2	1	-	2	2	1	1	Moderate
Zanjani 2013	2	2	1	-	2	3	1	1	Moderate
Zimmerman 2004	3	2	3	-	3	-	3	3	Weak

1=strong; 2=moderate; 3= weak.

Appendix D. UK Data Service User Licence

UK Data Service

End User Licence

PUBLIC
31 January 2017
Version: 07.00

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E susan@essex.ac.uk
ukdataservice.ac.uk

Contents

1. End User Licence (EUL) Text

This Agreement is made between you and the University of Essex (also referred to as the "registrar") and the service funders in order to provide you (the "End User") with the right to use the collections provided via the UK Data Service and the UK Data Archive, according to the terms below.

In this agreement:

"**Data Team**" means in relation to a particular data collection, the registrar, the relevant data service providers, and (to the extent that the Special Conditions and/or metadata specific to a particular data collection expressly provide) the service funders, data collection funders and/or original data creators or depositors.

"**data service provider**" means the persons or organisations that directly provide you with the data collections (on behalf of the service funder). The data service provider for a particular data collection is identified in the Special Conditions and/or metadata applicable to that data collection;

"**service funder**" means the persons or organisations that fund the data service provider as defined above. The service funder for a particular data collection is identified in the Special Conditions and/or metadata applicable to that data collection;

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"**original data creator or depositor**" means the persons or organisations that originally collected, created or deposited the materials making up the data collections and/or who own the intellectual property rights in the data collections. The original data creator or depositor for a particular data collection is identified in the Special Conditions and/or metadata applicable to that data collection;

"**registrar**" means the person or organisation responsible for the system that registers End Users and issues them with End User Licences (being the University of Essex);

"**Special Conditions**" means any further conditions applicable to the use of one or more data collections by an End User, as notified to the End User in accordance with paragraph 5 of the End User Licence;

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I (the "End User") agree to the following conditions of use in consideration of the data collections being made available to me through the various contributions of each member of the Data Team:

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3. That this Licence does not operate to transfer any interest in intellectual property from the data collection funders, service funder(s), the data service providers, the original data creators, producers, depositors, copyright or other right holders (including without limitation the ONS or the Crown) to me. That any rights subsisting in materials derived now or in the future from the data collections which are the intellectual property of the Crown are hereby assigned (by way of assignment of present and future intellectual property) to the Crown by this Licence to the extent not already vested in the Crown. To take all steps necessary to give effect to this Clause (including by executing further written documentation).

4. That the Licence and the data collections are provided by the Data Team on an "as is" basis and without warranty or liability of any kind. Any representations or warranties given by any member of the Data Team relating to this licence, expressed or implied, are excluded to the maximum extent permitted by law.

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6. To give access to the data collections, in whole or in part, or any material derived from the data collections, only to registered End Users with a registered use who have entered into an End User Licence and accepted the relevant Special Conditions, such as a Commercial Licence, necessary to access and use the data collections (with the exception of data collections or material derived from data collections supplied for the stated purpose of teaching and shared under the terms and conditions of the Access Agreement for Teaching or included in publications made for the purposes set out in paragraph 2).

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10. To supply the relevant data service provider with the bibliographic details of any published work based wholly or in part on the data collections.

11. That the members of the Data Team may hold and process any personal data submitted by me for validation and statistical purposes, and for the purposes of the management of the service or for any other lawful purpose notified to me and to which I have consented under this Agreement in relation to a particular data collection, and they may also pass the information on to other parties such as: (i) depositors and distributors of material contained in or accessed via the data service provider; (ii) copyright and other intellectual property rights owners whose material is held by the data service provider; as well as (iii) each member of the Data Team's organisation and (iv) my own institution or organisation, in compliance with the Data Protection Act 1998.

12. To notify the data service provider of any errors discovered in the data collections.

13. That any personal data submitted by me is accurate to the best of my knowledge, and that any changes in that personal data, including my educational or employment status, will be made known to the registrar at the earliest possible opportunity.

14. To meet any charges that may from time to time be levied by any member of the Data Team for the supply of the data collections including, where relevant, annual service fees and royalty fees.

15. At the conclusion of my research (or if earlier at any time at the request of a member of the Data Team), to offer for deposit in the data collection(s) on a suitable medium and at my own expense any new data collections which have been derived from the materials supplied or which have been created by the combination of the data supplied with other data. The deposit of the derived data collection(s) will include sufficient explanatory documentation to enable the new data collection(s) to be accessible to others.

16. Will, at the end of the access period, destroy all copies of the data, including temporary copies, printed copies, personal copies, back-ups, subsets of variables/cases, derived datasets and all electronic copies including copies held on portable media e.g. CD/DVD/memory stick;

17. Will ensure that the data are destroyed to the standards specified in the Microdata Handling and Security: Guide to Good Practice.

18. I understand that non-compliance with any of the provisions of this Agreement will lead to immediate termination of my access to all services provided by the Data Team either permanently or temporarily, at the discretion of a member of the Data Team, and m0ay result in legal action being taken against me. I understand that where there is compliance with this Licence, it may be terminated, or its terms altered, by a member of the Data Team either after 30 days' notice; or, if a service charge has been paid in advance, at the end of the period for which payment has been made, whichever is the longer. The failure to exercise or delay in exercising a right or remedy provided by this Agreement or by law does not constitute a waiver of the right or remedy or a waiver of other rights or remedies.

DISCLAIMERS

To the extent that applicable law permits:

a. The members of the Data Team bear no legal responsibility for the accuracy or comprehensiveness of the data supplied.

b. The members of the Data Team accept no liability for, and I will not be entitled to claim against them in respect of, any direct, indirect, consequential or incidental damages or losses arising from use of the data collections, or from the unavailability of, or break in access to, the service, for whatever reason.

c. Whilst steps have been taken to ensure all licences, authorisation and permissions required for the granting of this Licence have been obtained, this may not have been possible in all cases, and no warranties or assurance are given in this regard. To the extent that additional licences, authorisations and permissions are required to use the data collections in accordance with this Licence, it is the End User's responsibility to obtain them.

d. I agree to indemnify and shall keep indemnified each member of the Data Team against any costs, actions, claims, demands, liabilities, expenses, damages or losses (including without limitation consequential losses and loss of profit, and all interest, penalties and legal and other professional costs and expenses) arising from or in connection with any third party claim made against any member of the Data Team relating to my use of the data collections or any other activities in relation to the data where such use is in non-compliance with this licence.

If the whole or any part of a provision of this Agreement is void, unenforceable or illegal for any reason, that provision will be severed and the remainder of the provisions of this Agreement will continue in full force and effect as if this Agreement had been executed with the invalid provision eliminated.

This Agreement may be enforced separately in relation to each data collection provided to the End User by any member of the Data Team and the End User. No other persons may enforce this Agreement under the Contract (Rights of Third Parties) Act 1999.

This Agreement (which is the entire agreement between the parties and supersedes any previous agreement between them) may be varied in writing by agreement of the relevant service funders, the registrar, and the End User (who may give its consent to such variations by electronic means). No consent from any other party is required to vary or rescind this Agreement.

This Agreement and any documents to be entered into pursuant to it shall be governed by and construed in accordance with the laws of England and Wales and each Party irrevocably submits to the exclusive jurisdiction of the courts of England and Wales over any claim or matter arising under or in connection with this Agreement and the documents entered into pursuant to it.

2. End User Licence (EUL) Summary text

Eighteen points to help you understand the End User Licence (EUL). These pointers are for general guidance and you must read and understand the full EUL before agreeing to it. By accepting the EUL, you agree:

1. to use the data in accordance with the EUL and to notify the UK Data Service of any non-compliance you are aware of
2. not to use the data for commercial purposes without obtaining permission and, where relevant, an appropriate licence if commercial use of the data is required
3. that the EUL does not transfer any interest in intellectual property to you
4. that the EUL and data collections are provided without warranty or liability of any kind
5. to abide by any further conditions notified to you
6. to give access to the data collections only to registered users with a registered use (who have accepted the terms and conditions, including any relevant further conditions). There are some exceptions regarding the use of data collections for teaching and the use of data collections for Commercial purposes set out in an additional Commercial Licence.
7. to ensure that the means of access to the data (such as passwords) are kept secure and not disclosed to anyone else
8. to preserve the confidentiality of, and not attempt to identify, individuals, households or organisations in the data
9. to use the correct methods of citation and acknowledgement in publications
10. to send the UK Data Service bibliographic details of any published work based on our data collections
11. that personal data about you may be held for validation and statistical purposes and to

manage the service, and that these data may be passed on to other parties
12. to notify the UK Data Service of any errors discovered in the data collections
13. that personal data submitted by you are accurate to the best of your knowledge and kept up to date by you
14. to meet any charges that may apply
15. to offer for deposit any new data collections which have been derived from the materials supplied
16. will, destroy ***all*** copies of the data to the standards specified in point 1.16
17. will ensure that the data are destroyed to the standards specified in the Microdata Handling and Security: Guide to Good Practice;

18. that any non-compliance with the EUL will lead to immediate termination of your access to the services and could result in leg

Appendix E. Center for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977)

Now think about the past week and the feelings you have experienced. Please tell me if each of the following was true for you much of the time during the past week.

(Please answer *yes* or *no*)

Much of the time during the past week…

1. you felt depressed during much of the last week?

2. you felt that everything you did was an effort?

3. your sleep was restless?

4. you were happy?

5. you felt lonely?

6. you enjoyed your life?

7. you felt sad?

8. you could not get going?